Consumers International

Green testing

Recyclability, repairability and upgradability: A practical handbook for consumer organisations

Acknowledgements

This handbook was produced by Consumers International's Programme for Developed Economies and Economies in Transition, with the financial support and co-operation of the European Commission Directorate General XXIV (Consumer Policy and Consumer Health Protection).

Consumers International would like to thank its member organisations who took part in the project (listed in the Appendix to the Introduction & background section), and in particular the members of the expert panel for their work and advice:

Norman Crothers (Australian Consumers' Association, Australia)
Georg Daverda (Verein für Konsumenteninformation, Austria)
Isabelle Convié (Verbruikersunie, Belgium)
Barbara Moretti (Bureau Européen des Unions de Consommateures, Belgium)
Poul Wendel Jessen (Forbrugerrådet, Denmark)
Hans-Peter Brix and Frank Alleweldt (Stiftung Warentest, Germany)
Bodo Tegethoff (Arbeitsgemeinschaft der Verbraucherverbände, Germany)
Tilmann Höhfeld (Institut Für Angewandte Verbraucherforschung e.V, Germany)
Connie Lau (Hong Kong Consumer Council, Hong Kong)
Lars Jonsson (Konsumentverket, Sweden)
Jane Lee (Consumers' Association, UK)
Jill Johnstone (National Consumer Council, UK)
Kim Healy (International Consumer Research and Testing, UK)
Carolyn Nunley (Consumers' Union, USA)

Project leader: Gerjan Huis in't Veld, Consumentenbond, The Netherlands

Researchers: Ronald Luijk and Tom Geldhof, Consumentenbond

Project manager: Anna Fielder, Consumers International

Project assistant: Suzanne Gribble, Consumers International

Report editor: Judith Gubbay

Designed and produced by Steve Paveley

ISBN 19023 91 15 2

This report is part of the series produced as part of a Consumers International project: *Support to consumer organisations in promoting sustainable consumption*.

Others in the series are:
Green guidance (July 1998)
Green testing (September 1999)
Green claims (November 1999)
Green labels (November 1999).

Contents

Introduction & background

Contents:

Introduction

When former IOCU (now Consumers International, CI) organised its 'Beyond the Year 2000: the Transition to Sustainable Consumption' conference in 1993, the term 'sustainable consumption' was new to many consumer organisations. We have come a long way since then, although not far enough. On the threshold of the year 2000, we are still busy trying to integrate sustainability into our work on behalf of consumers.

What is sustainable consumption, and why are we trying to achieve it? According to the 1986 United Nations Guidelines for Consumer Protection: 'sustainable consumption includes meeting the needs of present and future generations for goods and services in ways that are economically, socially and environmentally sustainable'.[1]

That sounds like a wonderful idea, of course, but is anyone doing more than pay lip service to it? The evidence is that they are. Governments and inter-governmental organisations like the Nordic Council and the European Commission are promoting sustainability in both production and consumption. Manufacturers are working on more sustainable products, mainly through better product design; in some cases, unsustainable products are being replaced by more sustainable services. Meanwhile, many consumer organisations have officially adopted a commitment to sustainability in their mission statements.

But what do mission statements and government policies really mean? Do they really encourage consumers to move towards sustainability in their everyday business and home lives? Do consumer organisations really give practical advice on how to live in a more sustainable way? The answer is 'yes and no'.

The products consumers buy today are more energy-efficient than the old ones they replace. On the other hand, consumers now have a larger number of energy-using products in their homes than they had in the past. The paradox extends to food: consumers now buy more organic foods, but at the same time they consume more imported vegetables and fruit which involves a greater use of polluting – and thus unsustainable – transport.

Consumer organisations themselves already do a lot to promote sustainability, although they could do better. *Green guidance*[2], the report of CI's first sustainable consumption project, gives a 'state-of-the-art' picture of what 11 consumer organisations in different parts of the world already do (and don't do) about sustainability, in three fields: information on domestic appliances and their life-cycles (including cases studies on washing machines, laundry detergents, televisions, computers and coffee-makers); product testing and the environmental impact of those products (including case studies on cars and tyres, refrigerators and freezers, video cassette recorders and household chemicals); and environmental information, including regulation and 'green claims'.

[1] Guidelines for Consumer Protection, United Nations, New York, 1986

[2] Green guidance - How consumer organisations can give better advice on putting sustainable consumption into practice: An international study, CI, 1998

The work that underpins this handbook starts at the point where *Green guidance* finished, taking the vital next step of incorporating the concept of sustainability into the practice of consumer information and testing. This study (which was part of the Consumers International '*Support to consumer organisations in promoting sustainable consumption*' project), establishes a methodology for testing recyclability, repairability and upgradability, and includes a complete 'green' test programme for televisions.

Until now, product 'sustainability' work by consumer organisations has usually concentrated on energy saving – indeed, the two have often seemed synonymous. Consumer organisations have been testing the energy use of appliances for decades – admittedly because of the link between energy saving and money saving, rather than as an aspect of sustainability. There is still scope to improve their energy-use testing, mainly by giving more importance to energy in the overall test result, and by consequently looking more at 'small' energy losses like those in the stand-by or 'off' positions of appliances. But, as *Green guidance* showed, consumer organisations are already quite good at informing consumers and influencing manufacturers where energy saving is concerned.

Sustainability is about more than just energy saving, however. It also implies: the absence of toxic or hazardous substances in products; maximising a product's life-cycle (thus minimising the use of new raw materials); and, finally, disposing of products in the least environmentally harmful way.

These aspects have been little recognised in the concept of sustainability in general, and in consumer work in this field in particular. They are also especially relevant to consumers, who face problems when appliances break down, and who need to dispose of them when they are no longer usable.

It is for these reasons that we have chosen to make recyclability, repairability and upgradability (the late-20th-century alternative to repair) the focus of this second project. All three are less widely recognised, and more in need of work than energy saving. This project uses the same case study products as in *Green guidance* – washing machines, computers, televisions and coffee-makers – and includes the first 'green' test programme for colour televisions.

This handbook is not intended to be a 'fun read', but an essential working document for testers and consumer organisations. It gives definitions and preconditions of sustainability, focusing on recyclability, repairability and upgradability. It gives case studies on the four product groups, plus flow charts, checklists and guidelines of processes, life-cycle scenarios, sensitivity analyses, assessment schemes, and proposals for weighting and rating.

The objective of this project is to provide useful methodological tools to be used, in a practical way, to integrate sustainability into the everyday testing, informing and lobbying work of consumer organisations. So this document is not a report to be read, but a handbook to be used.

If consumer organisations are prepared to put these tools to work, this handbook will enable them to promote sustainable consumption more and better than before. Its success will be measured positively when, as we sincerely hope, its use by consumer organisations influences consumers to behave in a more sustainable way.

Background

1 Sustainable consumption

In developed economies, the consumption of goods and services is the main cause of environmental degradation and damage. The pattern of consumption has a direct influence on the environment, through the use of natural resources and energy and through the production of pollution and waste.[3]

DEFINITION: Sustainable consumption
'Sustainable consumption includes meeting the needs of present and future generations for goods and services in ways that are economically, socially and environmentally sustainable.'[1]

One key element in the transition to sustainable consumption will be to find ways for consumers in the affluent countries of the North to maintain or improve the high quality of their lives while using fewer resources and energy, and creating far less pollution. The starting point of this research is how the existing rate of consumption can become less detrimental to the environment.[3]

Consumers can, by their choices, contribute to an increased demand for goods that are more environmentally-friendly – and thereby stimulate the development of more environmentally friendly production in industry.[3] But they need accurate information about links between consumer behaviour and environmental impact. Most consumers are aware of environmental problems from reports in the media, but they often lack sufficient information to make the right choices.[3]

Consumers need quantitative facts and figures to make a balanced choice between products; they also need to be motivated to change wasteful or ecologically damaging lifestyles.

Sustainable consumption is achieved by:

- minimising energy consumption
- sustainable use of resources and reduction of waste.

Sustainable consumption is a process of transition in which industrial processes, products and services are adjusted to current and future needs, and are detached from the development of long-term environmental degradation. It also implies changes in consumer attitudes and behaviour. Much of the challenge in achieving sustainable consumption lies in better environmental design of appliances.

DEFINITION: Environmental design
'The design methodology whereby design decisions are directed as much by the environment as by other, more traditional values such as financial returns, quality, functionality, ergonomics, aesthetics and image.[4]

The main aspects of environmental design are:

- efficient energy use
- selective use of materials, and material reduction
- life-span extension of appliances (repairability, upgradability)
- recyclability.

---

[3] Environmental impact of consumer goods, TemaNord 1997:609, Nordic Council of Ministers, Copenhagen 1997
[4] Brezet, Han, Handleiding voor milieugerichte produktontwikkeling, SDU Uitgeverij, 's-Gravenhage, 1994

2 Life-span extension and environmental impacts

DEFINITION: Life span
'The time between introduction of the appliance on to the market and final disposal of the appliance as waste.'[5]

DEFINITION: Life-span extension
'Longer or intensified use of an appliance. Longer use of an appliance can be attained by repairing and / or upgrading. Intensified use of an appliance can be attained by shared use or leasing.'[6]

2.1 Technical, economic and psychological life span

The life span of an appliance is, of course, mainly determined by the behaviour of consumers themselves. At the moment of disposal the decision to end the life span of the appliance has been made. Distinctions can be drawn between the technical, the economical and the psychological life span of household appliances.[5]

Technical life span
The end of a product's technical life span has been reached when consumers, or retailers, manufacturers, second-hand dealers or waste collection services, assess that the appliance cannot be repaired because of wear or failure.

Nowadays, most appliances can be repaired, but in many cases this doesn't happen due to high repair costs. So technical life span rarely determines the life span of appliances: the principal factors are economic and psychological.

Economic life span
The end of a product's economic life span is reached when consumers, or retailers, manufacturers, second-hand dealers or waste collection services, assess that it is too expensive to continue using the appliance. The costs of use, maintenance and repair are too high, compared with the cost of purchase and the advantages of a new appliance.

Psychological life span
The end of a product's psychological life span is reached when consumers decide to dispose of, replace, or buy a new appliance for psychological reasons.

To some consumers the psychological life span of an appliance is reached before its technical or economical life span is finished. Other consumers like to have products that last a lifetime; for them, the psychological life span is of less importance.

There are also fashionably designed products that consumers often dispose of fairly quickly for purely psychological reasons. The same applies to new technological products or features, like computers and mobile telephones, that are highly appealing to, and influence the social status of, certain consumer groups.

2.2 Product strategies

The influence of various product strategies on the environment was investigated in the Netherlands by CEA (Office on Communication and Advice on Energy and Environment), for the Dutch Ministry of the Environment. In the CEA study, three different product strategies were considered: the product innovation strategy, the product life-span extension strategy, and the recycling strategy.[7] In the CEA study, household appliances were divided into three relevant product groups: material products, energy & material products, and energy products.

DEFINITION: Material products
These need no energy, or hardly any, to operate. Their environmental impact is determined entirely by their material content (furniture, for example).

DEFINITION: Energy & material products
These use energy to operate, while the environmental impact of the materials is also relevant (washing machines and refrigerators, for example).

[5] Scholten, A.H., Kanis, H., Is levensduurbeleid levensvatbaar? Swoka, 1987
[6] Cramer, Jacqueline, Workshop 11April 1996 on increasing sustainability of consumer electronic products, Utrecht, Netherlands, 1996
[7] Loep, Levensduuroptimalisatie en de energie, economie, en ecologie aspecten van producten, Rapportnummer 9560 Eindrapport, CEA, December 1995

DEFINITION: Energy products
The environmental aspects of these products are mostly determined by their energy use during functioning (light bulbs, for example).

2.2.1 Product innovation strategy

In this strategy, the use of energy or the materials of the product its consumer phase are reduced by innovation. The product innovation strategy can considerably reduce the environmental impact.

2.2.2 Product life-span extension strategy

This strategy can be split into repair and upgrading. The product life-span extension strategy has a positive environmental effect on both material products and energy & material products, but none on energy products.

In most cases, product life-span extension does not increase energy use because the lack of innovation will generally be compensated for by the purchase of a new, innovative product after the old one has been disposed of – one with a lower energy use than a product with a shorter life span, that might have been bought earlier. Much of the missed innovation will be made up for when the product is later replaced. This assumes continuous innovation, as opposed to innovation made by sudden improvements.[8]

In the case of some energy products, such as light bulbs, a longer life span with old technology might even have a negative environmental effect.[6]

2.2.3 Product recycling strategy

Here, the materials of the appliance are recycled. The product recycling strategy has a positive environmental effect for material products and energy & material products, but none on energy products.

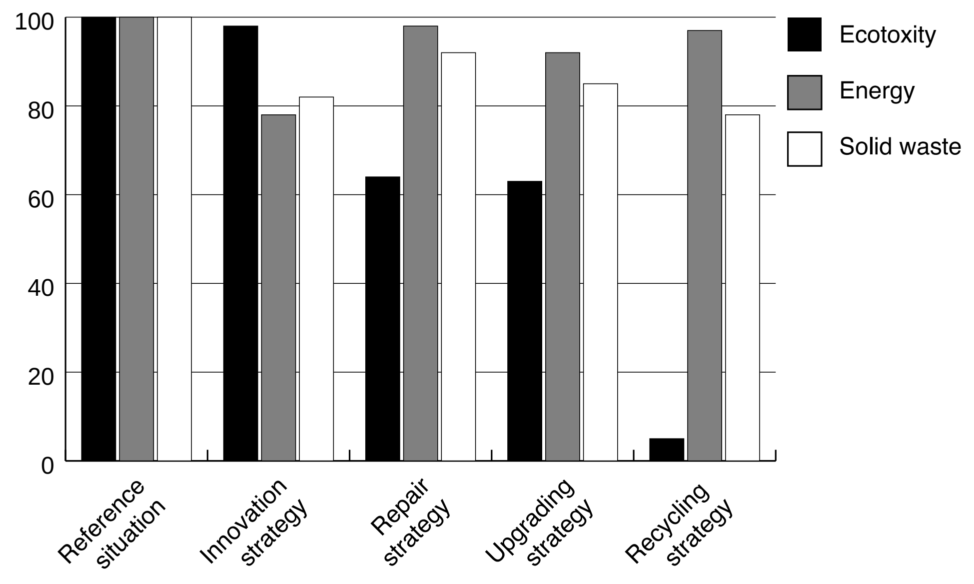
2.3 Case study: washing machines[7]

The washing machine is an example of a material & energy product. The consumer phase and the disposal phase both produce significant environmental impacts. The use of an average washing machine over 20 years was chosen as the functional unit for this case study.

The environmental impact of four different strategies has been calculated, based upon ecotoxicity, energy and solid waste – see Figure 1.[9]

In our example, the average washing machine has been defined as one that has a life span of 10 years, weighs 80 kg, and has an energy use

Figure 1. Life-cycle analysis results for four product strategies: washing machines



[8] T.J. Geldhof en H. Blaauwgeers,Levensduurverlenging; Onderzoeksverslag Consumentenbond, 1996
[9] European Proposal for a directive on waste from electrical and electronic equipment, 75/442/EEC, November 1998

of 231 kWh per year. Since the starting point is the usage of the functional unit over 20 years, a new washing machine will be bought after 10 years, and it will use 25% less energy than its predecessor. (The literature suggests this assumption is correct: energy use of washing machines has been reduced by 25% in the past 10 years.)

For the innovation strategy, the assumption was a 25% lower energy use than in the reference situation. This estimated innovation figure is fairly high. However, the difference between the energy use of the ‘average’ and the ‘economical’ washing machine is also large nowadays, so the assumed energy reduction is easily attainable by new technological developments in detergents or with the use of hot-fill.

In the repair strategy, repairing the washing machine results in a life span of 15 years. The extra energy used in making the repair is taken into account. The second washing machine is 37.5% more economical (as a result of innovation), and will be expected to last for another 5 years.

In the upgrading strategy, it is assumed that the appliance is taken back by the manufacturer after 10 years, and returned to the market after modification. This washing machine has an adapted washing programme, and the newest technology means it will use 25% less energy. For the modification, extra energy – namely 15% of the energy from the user phase – is taken into account.

Where recycling of materials is concerned, the starting point is that 100% of the materials used in the manufacture of the washing machine are recycled. Extra energy is needed for transport, dismantling and processing. The washing machine is made of recycled materials (mostly steel and aluminium).

From Figure 1 it appears that the innovation strategy reduces energy use by 23% (as expected, since the appliance is more economical), and leads to 17% less solid waste, but scarcely influences the ecotoxicity. In general, the life-span extension strategies have a positive effect on ecotoxicity and solid waste, but do little to improve on energy use. Indeed, it is striking that life-span extension does not lead to increased energy use. Replacing the washing machine will make up for a great deal of the ‘missed’ innovation.

The material recycling strategy scores very well on solid waste (a reduction of 23%), without increasing energy use. At the same time, the score for ecotoxicity is strongly decreased. This is caused by the reduction of lead emissions (originating from PVC). (Lead is dominant in the ecotoxicity calculation.)

2.4 Priority of strategies

According to the CEA study, of the three strategies, the product innovation strategy is the most profitable one for the environment. Next best is the product life-span extension strategy. On the whole, the greatest environmental benefit can be achieved by a combination of strategies. This applies particularly for the combination of product innovation and life-span extension.[7]

3 Disposal regulations of white and brown goods

3.1 Disposal regulations in EU countries

Regulations for the disposal of white and brown goods as set by the European Community are at the proposal stage: the EU directive on waste from electrical and electronic equipment will be in force as from 1 January 2004. The directive’s objective is the prevention and recovery of electronic waste, and to minimise the risks to, and impacts on, the environment associated with the treatment and disposal of end-of-life white and brown goods. It further aims to harmonise national measures.[9] In the European Union, disposal regulations for white and brown goods are at different stages of development from one country to another.

[10] Behrendt / Jasch / Peneda / Weenen, 1997

In Germany, integrated environmental legislation for avoiding waste, and for re-using, recycling and disposing of it (the Closed Substance Cycles Act) became effective in 1996. Besides integration, a major feature of this law is extensive waste management. German companies must come up with a waste prevention plan, and must regularly monitor and report on their waste flow. The main principles in German environmental management are the prevention principle and the 'polluter pays' principle. The resulting responsibilities are product stewardship and take-back obligations.[10] The new government recently put back on the agenda the 1992 draft ordinance on the recovery of waste from electrical and electronic equipment, but there are major obstacles to its implementation, such as whether municipalities or manufacturers should pay for collection, and whether retailers should be obliged to take goods back.[11]

In the Netherlands, the Removal of White and Brown Goods Act came into effect on 1 January 1999. Its aim is set up a seamless removal system for white and brown goods: re-using and recycling products and materials as much as possible, and limiting the environmental burden. If consumers buy a new white or brown product, they can return their old appliance to the suppliers, exchanging old for new. Consumers have to pay a levy on top of the purchase price for their old appliance to be removed. Manufacturers are responsible for the collection and end-of-life treatment of white and brown goods.[12]

In Sweden, legislation on electronic waste will be operational in the year 2000. Anyone who sells electronic appliances (manufacturers, importers and suppliers) must take back and dispose of unwanted appliances free of charge. Retailers must also take back an appliance even if they have not sold a new one.[12]

In Norway and Denmark, legislation is being drafted; consumers can, at no cost, return their old appliances to the municipality or supplier. Appliances are collected at regional collection points and dealt with by manufacturers. This is financed by a tax on new appliances.
In France, industry is looking at the possibilities of setting up a removal system.

In the United Kingdom, industry has taken the initiative (in the form of the Industry Council for Electronic Equipment), and investigated the possibilities of re-use and recycling of unwanted appliances. There are also initiatives at local level for the collection and removal of white and brown goods. The starting point for these is that manufacturers and importers must take more responsibility for their appliances at the disposal phase.[12] The Environment Act 1995 is concerned with legal and institutional arrangements for waste management. It also requires the development of a national waste strategy. The strategy paper 'Making Waste Work', published in 1996, provides an overall plan for waste, and paves the way for a statutory National Waste Strategy, as required under the Act. Although this is advisory and non-statutory, local authorities must take it into account when drawing up their plans.[13]

3.2 Disposal regulations in the US and other developed countries

In the United States, each state has some kind of appliance recycling programme. Since 1997, 21 states have banned white goods from landfill sites. Only Massachusetts has taken steps to eliminate electronic goods from landfill sites, and from July 1999 is banning the disposal of computers, monitors, televisions and other electronic goods.

In Japan, the Appliance Recycling Law was ratified in 1998, with take-back to be implemented on televisions, refrigerators, washing machines and air-conditioning systems in 2001, and computers in five to ten years.[14]

The disposal regulations of white and brown goods in many developed countries are summarised in Table 1.

---

[11] Sustainable consumption questionnaire, AGV, 1999
[12] Staatscourant, The official Journal of the Dutch Government, Removal of White and Brown Goods Act, 1997
[13] Sustainable consumption questionnaire, Consumers' Association, 1999
[14] The Journal of Sustainable Product Design, October 1998

Table 1: Disposal regulations of white and brown goods in developed countries

Countries	In force	In draft	In effect	Who pays?
Australia	No; none foreseen in the future[15]			
Austria	Electronic Waste Act, based mainly on German regulations		Since 1992 for refrigerators	For refrigerators, consumers pay 7.3 Euros for a coupon at time of purchase; take-back by retailers of other white goods costs consumers 14.5 Euros[16]
Belgium (Flanders)	Regulations on waste prevention and management: old for new take-back obligation[17]	From July 2004, retailers must take back all appliances; sale not necessary	As from 1 July 1999	No charge for consumers; producer or importer must pay at the end for removal
Denmark		Legislation in preparation		Taxation on new appliances
France		Removal infra-structure on voluntary basis		
Germany	Closed Substances Cycles Act: producer respon-sibility for all appliances brought on market after date of effect	Draft ordinance on the recovery of waste from electrical and electronic equip-ment from 1992	Since 1996	Removal is usually covered by municipal waste fees, ranging from 100-350 Euros per household per year[11]
Netherlands	Take-back regu-lation ‘old for new’ for white and brown goods		Since January 1999	Removal levy on new appliances of 9-18 Euros
Norway		Consumers can deliver white and brown goods to municipality or supplier		No charge for consumers at disposal
Sweden		Old-for-new take-back regulations; sale not necessary	As from 2000	

15 Sustainable consumption questionnaire, Australian Consumers’ Association, 1999
16 Sustainable consumption questionnaire, VKI, 1999
17 Sustainable consumption questionnaire, Verbruikersunie, 1999

Countries	In force	In draft	In effect	Who pays?
Switzerland	Take-back regulations, old-for-new, on electric and electronic appliances			For refrigerators, levy of 44 Euros
United Kingdom	No formal national schemes for collection and recycling of appliances; initiatives by The Industry Council for Electronic Equipment, and at local level[13]			In some cases old for new without charge
United States	21 states require recycling of white goods, banning them from landfill sites; Massachusetts also bans brown goods with screens from landfill sites[18]		Regulations in Massachusetts as from July 1999	In some cases, old for new without charge; hauliers charge $15-25; some municipalities charge by weight or volume

4 Waste collection of white and brown goods

4.1 Waste collection in EU countries

4.1.1 Current waste collection

Waste collection in the European Union currently differs from country to country, and even within countries. In Germany, end-of-life electronic appliances are collected from the roadside by the municipal waste services, which hand them over to private operators for further treatment.

In Austria, there is no standard national collection system for end-of-life electronic appliances. Collection is currently organised regionally.

In Sweden, collection of major white and brown goods is usually twice a year, and is taken care of by the municipality; the service is included in the normal waste collection charge. Refrigerators are the exception, and are collected at special disposal sites. There are also special waste collection centres where consumers can take their waste for disposal or for materials to be recycled.

In Denmark, the system of waste management is devolved to the municipalities. White goods are mainly disposed of through retailers, though consumers can also deliver them to special collection points. There are special collection points for brown goods. In a number of municipalities, the collection of white and brown goods is taken care of by the municipality's waste collection service.

In Belgium, consumers can deliver end-of-life appliances to container parks in all regions. In some municipalities there are also special collection services (separate from the municipal waste collection service). In Flanders, consumers can exchange old for new at the retailer.

In the Netherlands, there are several regulations, decrees, mutuality agreements

[18] Sustainable consumption questionnaire, Consumers' Union, 1999

(between governmental and industrial bodies) and voluntary measures on waste reduction. The most important ones are: a decree and mutuality agreement on packaging waste; regulations on car recycling; a decree on the disposal of white and brown goods; a decree on the disposal of batteries; several other laws and decrees on harmful substances; separate removal of organic waste, glass, paper, metals and small household chemicals.

In France, end-of-life white and brown goods are collected by the local community or by voluntary organisations, and temporary dumps are provided on a regular basis. Alternatively, consumers can take appliances to local rubbish tips.

In the United Kingdom, waste collection run at local level; there are no formal national schemes for collection and recycling of appliances. Local authorities have waste disposal sites (civil amenity sites) where consumers can take large household waste. Some retailers will remove an old appliance when delivering a new one.

4.1.2 Quantity of waste

The quantity of waste from electrical and electronic equipment is rapidly increasing as the number of electronic products grows dramatically. In 1998 the countries of the European Union were expected to produce 6.5-7.5 million tonnes per year, which represents approximately 1% of total EU solid waste.

4.2 Waste collection in the United States

4.2.1 Current waste collection

Consumers are generally charged $15-25 by special hauliers to come and pick up a major white good. Some municipalities will pick goods up for free, but usually only once or twice a year. Some retailers will remove old white goods free of charge from consumers who buy new ones. Small electronic equipment and computers are generally taken away at no cost, although a number of municipalities charge consumers for waste disposal by weight or volume – so those with bigger bags or bins pay more.

4.2.2 Quantity of waste

In the USA, major white goods accounted for 3.4 million tonnes of municipal solid waste generated in 1995, 1.6% of the total waste output. Between six and 13 million computers are disposed of as waste every year. The US Environmental Protection Agency estimates that about 700,000 tons of small appliances were discarded in municipal waste in 1995. This represents about 0.5% of total waste.[14]

4.2.3 Current destination of white and brown goods

Of the total white goods disposed of as waste in the USA in 1995, 75% was recycled (comprising about 10% of all steel processed by the recycling industry). Ten per cent of computers taken out of service each year are recycled, 15% go to landfill, and the remaining 75% are stockpiled (stored in basements and attics). They will probably be dumped later.

Appendix: Participating organisations

AUSTRALIA

Australian Consumers' Association (ACA)
57 Carrington Road
Marrickville NSW 2204
Australia
Tel: +61 29 577 3218
Fax:+61 29 577 3377
E-mail: ausconsumer@choice.com.au
Web site: http://www.sofcom.au

Norman Crothers

AUSTRIA

Verein für Konsumenteninformation (VKI)
Linke Wienzeile 18
A-1060 Vienna
Austria
Tel: +43 1 588 770
Fax: +43 1 588 7773
E-mail: konsument@vki.or.at
Web site: http://www.vki.or.at/vki/

Georg Daverda

BELGIUM

Association des Consommateurs /Verbruikersunie (VU)
13 Rue de Hollande
1060 Brussels
Belgium
Tel: +32 2 542 3241
Fax:+32 2 542 3250

Isabelle Convié

Bureau Européen des Unions de Consommateurs (BEUC)
Avenue de Tervueren 36 Bte 4
1040 Brussels
Belgium
Tel: +32 2 743 1590
Fax:+32 2 735 7455
E-mail: consumers@beuc.org
Web site: http://www.beuc.org

Barbara Moretti

DENMARK

Forbrugerrådet (FB)
P O Box 2188
DK-1017 Copenhagen K
Denmark
Tel: +45 33 136 311
Fax:+45 33 134 115
E-mail: fbr@fbr.dk
Web site: http://www.fbr.dk

Poul Wendel Jessen

GERMANY

Stiftung Warentest
Lützowplatz 11-13
10785 Berlin
Germany
Tel: +49 30 26 31 2329
Fax:+49 30 26 31 2424
E-mail: test@stiftung-warentest.de
Web site: http://www.stiftung-warentest.de

Frank Alleweldt and Hans-Peter Brix

Arbeitsgemeinschaft der Verbraucherverbände (AgV)
Heilsbachstrasse 20
53123 Bonn
Germany
Tel: +49 228 64 890
Fax:+49 228 644 258
E-mail: mail@agv.de
Web site: http://www.agv.de

Bodo Tegethof

Institut Für Angewandte Verbraucherforschung e.V (IFAV)
Aachener Strasse 1089
50858 Köln (Junkersdorf)
Germany
Tel: +49 2234 407712
Fax: +49 2234 407722
E-mail: ifav.koeln@t-online.de

Tilmann Höhfeld

HONG KONG

Hong Kong Consumer Council (HKCC)
GPO Box 191
North Point
Hong Kong
Tel: +852 2856 3113
Fax:+852 2856 3611
E-mail: cc@consumer.org.hk
Web site: http://www.consumer.org.hk

Connie Lau

THE NETHERLANDS

Consumentenbond (CB)
Postbox 1000
2500 BA, Den Haag
The Netherlands
Tel: +31 70 445 4545
Fax:+31 70 445 4590
E-mail: cbemail@euronet.nl
Web site: http://www.consumentenbond.nl

Project leader: Gerjan Huis in t'Veld
Researchers: Ronald Luijk and Tom Geldhof

SWEDEN

Konsumentverket / KO (KV)
S - 118 87 Stockholm
Sweden
Tel: +46 8 429 0550
Fax:+46 8 429 8900
E-mail: konsumentverket@kov.se

Lars Jonsson

UNITED KINGDOM

Consumers' Association (CA)
2 Marylebone Road
London NW1 4DF
United Kingdom
Tel: +44 171 830 6000
Fax:+44 171 830 6220
E-mail: which@which.net
Web site: http://www.which.net

Jane Lee

National Consumer Council (NCC)
20 Grosvenor Gardens
London SW1W ODH
United Kingdom
Tel: +44 171 730 3469
Fax:+44 171 730 0191
Email: admin@nccuk.demon.co.uk

Jill Johnstone

International Consumer Research and Testing (ICRT)
First Floor
111 Baker Street
London W1M 1SE
United Kingdom
Tel: +44 171 486 3200
Fax:+44 171 486 5055
E-mail: intest@which.co.uk

Kim Healy

UNITED STATES

Consumers' Union of U.S, Inc. (CU)
101 Truman Avenue
Yonkers, New York 10703-1057
United States
Tel: +1 914 378 2303
Fax:+1 914 378 2918
Web site: http://www.ConsumerReports.org

Carolyn Nunley

Recyclability module

Contents:

Reader’s guide

The methodology for developing the recyclability checklists and guidelines consists of three parts:

1. definitions and preconditions
2. case studies
3. checklists and guidelines.

The methodology development is shown in Figure 1.

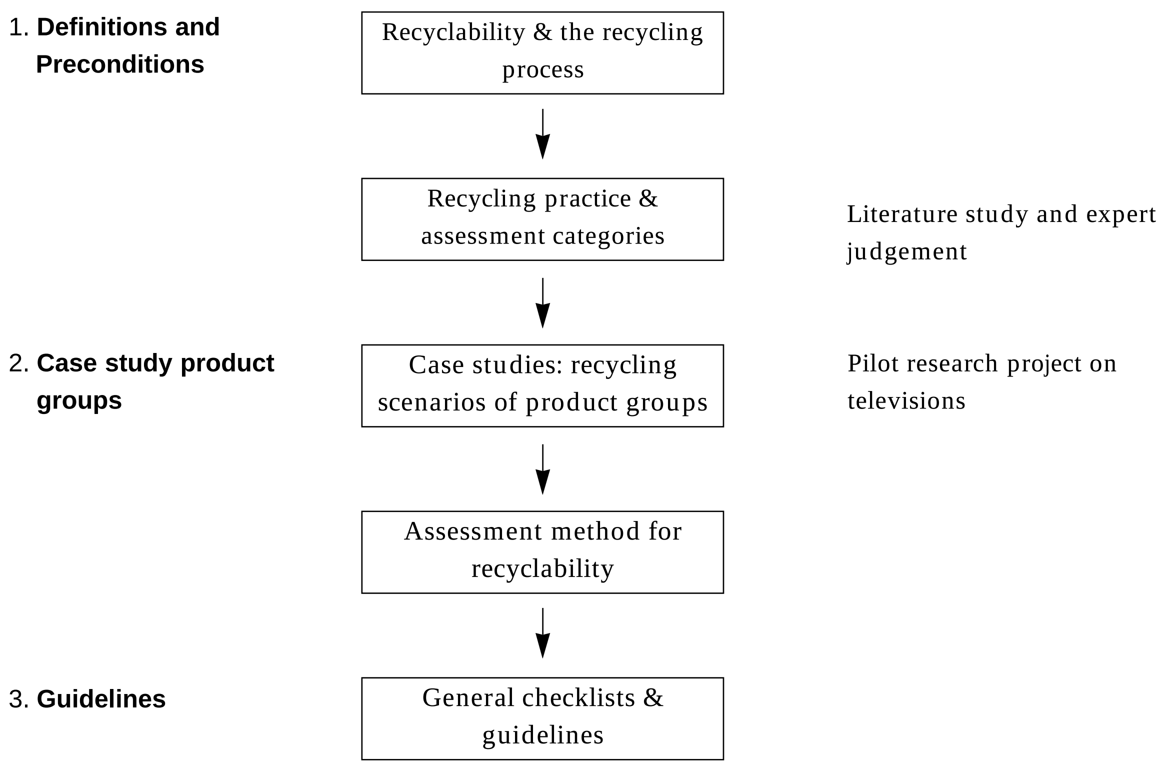
The checklists and guidelines are intended to be used by consumer organisations wishing to start a project on recyclability. These guidelines are proposals for the assessment of recyclability, and summarise the available consumer-oriented research options.

1 Definitions and preconditions

This section gives definitions of recyclability and recycling, and discusses the phases which household appliances undergo in the recycling process. The different recycling scenarios currently possible for household appliances are also discussed, as are international recycling practices. The assessment categories for recyclability were developed on the basis of the flowchart of the recycling process (Figure 2).

The available sources were: existing literature, the practices of recycling centres, and the expertise of the Dutch Consumentenbond

Figure 1. Methodology for developing the recyclability checklists and guidelines



and the TNO, Institute of Industrial Technology, the Netherlands.

2 Case studies

The case study product group consists of washing machines, computers and televisions. The case studies were chosen as a model for the different recycling scenarios, and were based, as before, on literature review, the practices of recycling centres, and the expertise of both the Dutch Consumentenbond and TNO, Institute of Industrial Technology. The constituents of the product groups and the current recycling scenarios are discussed within each case study.

This section also covers the proposed method for assessing recyclability. This recyclability assessment method describes in detail what steps have to be taken to assess the recyclability of household appliances. The results are the assessment criteria, ratings for the criteria, and weightings for the assessment categories. This method has been used for televisions, and a pilot disassembly test for televisions was carried out for this purpose (see Appendix 3A).

The weighting of the assessment categories was carried out using DFE (Design For Environment), a software tool of TNO, Institute of Industrial Technology;[1] this software was developed for designers, and enables them to make a financial and environmental end-of-life evaluation of a prototype.

3 Checklists and guidelines

This section outlines general checklists and guidelines. Different checklists were developed for the possible recycling scenarios. The guidelines consist of the key questions for consumers, assessment criteria and, where applicable, a proposal for rating and weighting, and research methods for each phase of the recycling process.

[1] DFE is commercially available from TNO Institute of Industrial Technology, Product Development Division, the Netherlands

1 Definitions and preconditions

1.1 Recyclability

Once an appliance has been discarded by the consumer and has been through a collection infrastructure, its possible end-of-life-destinations are landfill, incineration or recycling. Landfill is the least desirable destination due to the high costs, especially in the case of components containing environmentally harmful substances. For sustainable consumption, recycling has priority over incineration.

In general terms, recyclability is defined as 'the potential to re-use appliances, and components and / or materials used in them, after they have been abandoned by consumers'[2] although there is also a more specific technical definition – see below. In this context, re-use of components is considered as recycling. In the scope of this study, the definitions of recycling and recyclability are narrowed down to the recovery of materials, and the term recycling refers to material recycling. Re-use of components will, however, be discussed.
In general, if an appliance is disassembled, re-use of valuable components is preferable to recycling the materials.

DEFINITION: Re-use of components
'Putting the component back into working order at a specified level of quality. This quality level can be lower, equal to or higher than the original quality of the assembly, i.e. when manufactured for the first time.'[3]

DEFINITION: Recycling
'The recovery of materials from discarded products and components after possible disassembly has been applied.'[4]

DEFINITION: Recyclability
The ability to achieve the required level of separation of the product into pure materials with the required purity of materials and level of recycling.

Recyclability is determined by the choice of materials used in the appliance, by the length of disassembly time of the main components and of components with environmentally harmful substances, and by the ease of identification of materials of these components. Low recyclability appliances are not designed for disassembly and recovery: the percentage of recovered materials is low, given the current recycling processing for the product group. Medium recyclability appliances are products with an improved design that facilitates the disassembly process. High recyclability appliances are sustainable appliances, specifically designed for disassembly. This implies a high percentage of recovered materials, and reduced environmental impact.

DEFINITION: Rate of recycling
The percentage of recovered materials by weight of the appliance. Recovered materials are the materials resulting from the recycling process that can be delivered to the raw material industry.

1.2 The recycling process

The phases of the recycling process are illustrated in Figure 2.[5] The recycling process

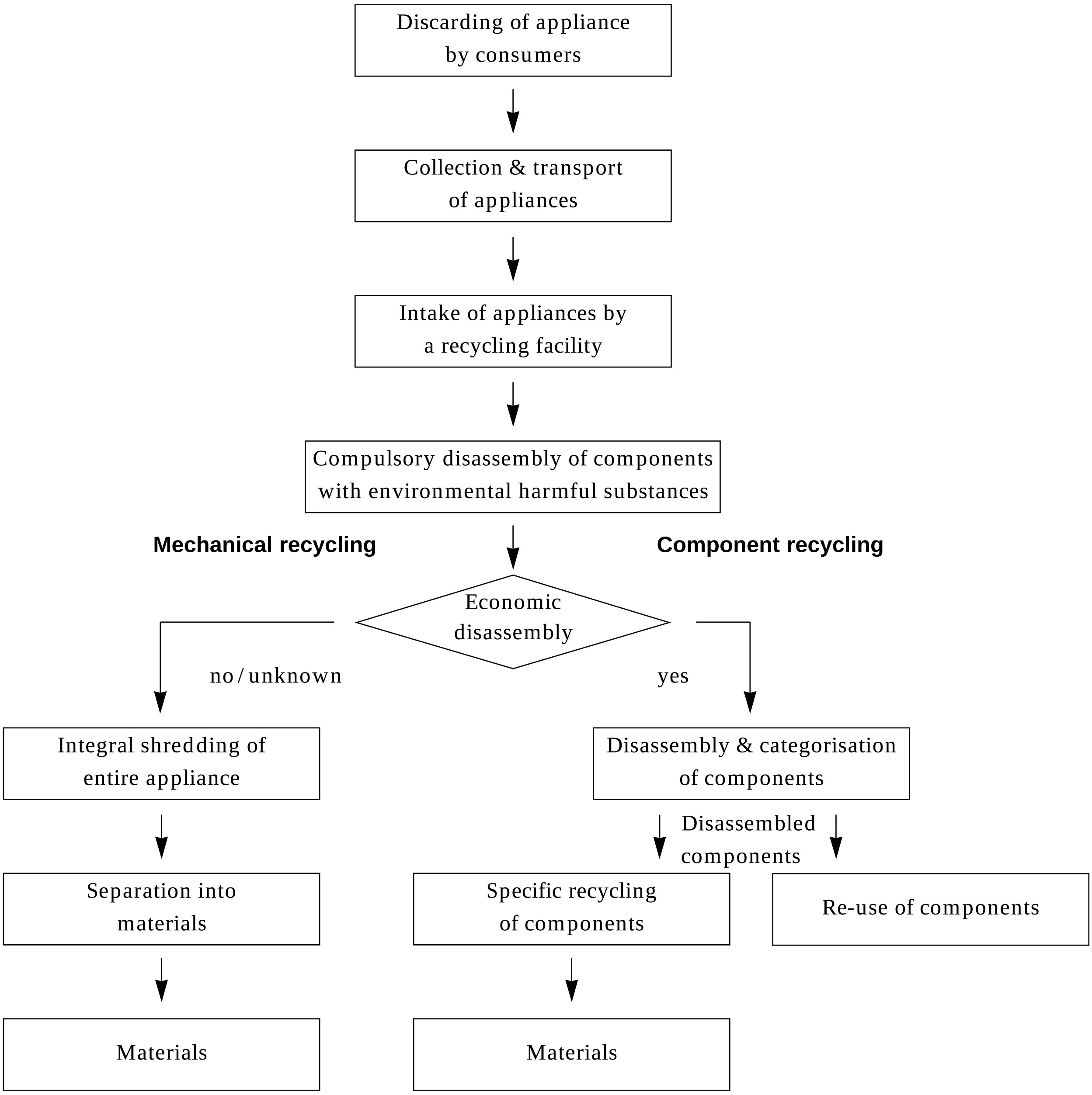
[2] Chemielinco, Beoordelingsmethode voor de recyclebaarheid van huishoudelijke apparaten, projectnummer 94665, 1995
[3] Krikke, Harold; Recovery strategies and reverse logistic network design, Thesis, University of Twente, Enschede, 1998
[4] Penev, Kiril Dimitrov; Design of Disassembly Systems, a systematic approach; 1997 (The word 're-use' in Penev's definition was altered to 'recovery' because 're-use' refers to re-use of components)
[5] The flowchart of the recycling process was developed as part of this project

starts with the discarding of an appliance by a consumer to the municipal collection service, a collection point, or where specific, old-for-new take-back regulations apply, to the retailer. The discarded appliance is then collected and transported to the recycling centre.

Before recycling takes place, components with environmentally harmful substances are compulsorily disassembled. Recycling centres should handle harmful substances correctly and avoid emissions of these substances into the environment. Recycling can be divided into mechanical recycling and component recycling.[6] With mechanical recycling, the entire appliance is treated in a mechanical shredder. In the case of component recycling, the appliance is disassembled into its components, which are then re-used or recycled.

The phases which are of concern for the assessment of recyclability by consumer organisations are: discarding of appliances by consumers, intake of appliances by a recycling centre, compulsory disassembly of components with environmentally harmful substances, mechanical recycling, and component recycling.

Figure 2. Flowchart of the recycling process



[6] The term 'component recycling' was developed for this project.

1.2.1 Discarding of appliances by consumers

The manufacturer should give information in the user's manual about how and where consumers can dispose of the old appliance for collection and recycling. This information should include where consumers can take the old appliance, how to dispose of environmentally harmful materials or components, and what (electronic) components and materials it contains. Some manufacturers give a recycling guarantee. If an appliance contains rechargeable batteries, information about their removal should appear in the user manual.

1.2.2 Intake of appliances by a recycling centre

Collected and transported appliances from a particular product group are taken in huge containers or box pallets to a recycling centre dealing with numerous different product types from that one product group. After emptying the container or box pallet, the appliances are registered; information about each appliance is necessary for further treatment. According to the proposed European Directive on waste, manufacturers have to provide manuals that identify, as far as is needed by treatment centres, different electric and electronic components and materials, and the location of all dangerous substances and preparations in electric and electronic equipment.[7] Currently, a recycling centre can ask manufacturers for component lists of the appliances they produce. However, labelling is necessary for quick identification of materials.

1.2.3 Compulsory disassembly of components with environmentally harmful substances

Before recycling takes place, it is compulsory to disassemble the components of any appliance which contains environmentally harmful substances. If this does not happen, the material output will be categorised as chemical waste.

1.2.3.1 European Directive on waste

The proposed European Directive on waste from electrical and electronic equipment, November 1998, says that member states should ensure that the use of lead, mercury, cadmium, hexavalent chromium and halogenated flame retardants is phased out by 1 January 2004.

The European Directive also proposes that member states shall ensure that producers set up systems to provide for the pre-treatment of end-of-life electrical and electronic equipment that is separately collected and destined for landfill, incineration or recovery. Components containing the following environmentally harmful substances have to be removed:

- lead (except in cathode-ray tubes)
- mercury
- hexavalent chromium
- cadmium (appears in rechargeable NiCad batteries and LCD screens)
- polychlorinated biphenyls (appear in electrolyte capacitors on printed circuit boards of a height of more than 2 cm and a diameter more than 1 cm, or comparable volume)
- halogenated flame retardants (can appear in printed circuit boards, back panels of televisions and in the housings of computers)
- radioactive substances
- asbestos (can appear in small domestic appliances such as coffee-makers)
- beryllium.

1.2.4 Mechanical recycling

DEFINITION: Mechanical recycling
The process of shredding an appliance and separating material types.

A shredder is a technical device consisting of a set of rotating hammers or knives that demolish the discarded goods and produce a mixed output of different materials. From this mixed output, different materials are divided up by a range of separation techniques. The materials obtained may be ferrous materials,

[7] European proposal for a directive on waste from electrical and electronic equipment, November 1998

non-ferrous materials such as copper and aluminium, or glass or plastics. Separation techniques used include fixed magnetic field separation (for the ferrous metals), eddy current separation by changes in a magnetic field (for the non-ferrous metals), a wind sifter which separates solid particles of different density by means of an air flow, and possible separation of the plastics. The purity of the materials depends on the constituents of the product and the separation technique.

1.2.5 Component recycling

DEFINITION: Component recycling
Component recycling is the process of disassembly of the appliance and categorisation of components with the purpose of re-use or specific recycling. Component recycling always implies disassembly. Appliances to which component recycling applies should be designed for disassembly in order to minimise disassembly costs.

If the appliance contains valuable components which can be re-used, the appliance is disassembled to the point where the valuable components are removed (for example, the printed circuit boards of computers), and the remainder goes for recycling or incineration. The disassembled components are categorised according to their destination. Categorisation involves collecting all undamaged valuable components with the same function.

If the components of an appliance contain different materials which cannot enter mechanical recycling together, the destination is specific recycling. The appliance is then disassembled until these components are separated (for example, the picture tube and the printed circuit boards of a television). Categorisation involves collecting components of primarily the same material.

1.2.6 Disassembly

DEFINITION: Disassembly
'To take apart in constituent parts by means of various operations so that the obtained components are not broken and / or damaged.'[3]

DEFINITION: Economic disassembly
Performing a disassembly process that transforms inputs (discarded goods) into outputs (disassembled components); every output has an added value compared to its input. Starting points are landfill costs and collection costs.

DEFINITION: Optimal disassembly
'Disassembly of an appliance with as high as possible financial gain.' Optimal disassembly involves removal of valuable components and specific recycling of the remainder. The appliance is disassembled to the point where the valuable components are separated out. (Continuing disassembly increases the costs and is not financially beneficial.)

DEFINITION: Design for disassembly
'The aspect of the design methodology which takes into account future disassembly at the end-of-life stage of an appliance. Design for disassembly is influenced by the complexity of the appliance, detectability and accessibility of connecting parts, number of connections, variety of connecting parts, number of components, tool requirements, and automation of disassembly.'[8]

In principle, design for disassembly can be measured by disassembly time (an appliance with a complex construction takes more time to disassemble than one with a simple construction).

Disassembly is rated difficult when the accessibility of the connections is troublesome, when high precision is required to position the tool, or when much force is needed to loosen the connections.[9]

DEFINITION: Disassembly level
'The level of disassembly applied in the disassembly process. A high disassembly degree means full disassembly.'

The disassembly degree depends on the intended goal. If the goal is the lowest possible environmental impact of the end-of-life destination of the appliance, this will often be obtained by specific recycling of the

---

[8] Behrendt, Siegfried; Jasch, Christine; Peneda, Maria Constança; Weenen, Hans van; Life cycle design, a manual for small and medium -sized enterprises IZT Institute for& nbsp; Future studies and Technology Assessment, 1997
[9] Kroll, Ehud; Hanft, Thomas; Quantitative evaluation of product disassembly for recycling, Research in Engineering Design, Volume 10 number 1, 1998

components. The appliance then has to be fully disassembled. If the goal is the lowest possible reprocessing costs, then the appliance will be disassembled to a certain point, and the remainder recycled or incinerated.

1.2.7 Collecting components with the same function

Components destined for re-use are collected on the ‘same function’ criterion. On the disassembly line of a recycling centre, the appliances are disassembled to the point where the valuable components are removed. After disassembly, valuable components must be undamaged.

1.2.8 Collecting components of the same material

If the destination of the components is specific recycling, then components of the same material are collected. On a disassembly line of a recycling centre, the appliances are disassembled one after another. Disassembled components of the same materials are collected in large trays. In general, the following components are collected from electronic appliances:

- plastic housings
- electrical motors
- electronic components
- ferrous components
- aluminium components
- glass components
- cables
- batteries

1.2.8.1 Material labelling

Quick and unambiguous identification of the materials used in a component facilitates collection. This is of little concern where a manufacturer takes back its own appliances, but recycling centres have to deal with appliances of numerous manufacturers. Material labelling of components is mainly an issue with plastics (labelling according to ISO 11469), and with components which contain environmentally harmful substances. In the future, bar codes should be applied, allowing the plastics to be sorted by laser scanners.[10] The bar code can contain information about material composition, date of manufacture, harmful substances, and additives. A hand scanner for identification of plastics has been developed.[11]

Another technique for automatic sorting of the main recyclable plastics is infra-red radiation.[12]

Sony’s technology centre in Stuttgart, Germany, has proposed that appliances should incorporate an electronic module containing retrievable data on product materials. The module would be made to an industry-wide standard and accessible through a diagnostic connector.[13]

1.2.8.2 Material categorisation

Collecting components of the same material implies the selection and categorisation of components as valuable components, waste or chemical waste. In this sense, the maximum amount of material of the appliance that can be recycled is already determined to a certain level by categorisation (components selected as waste are not recycled). The category into which components are put depends principally on material value, amount of pure material, environmental harmfulness, and labelling. For complex appliances, the diversity of materials should be as minimal as possible.

Valuable components are those for which the material reprocessing has economic benefit. These are components with a significant ferrous, copper or aluminium content, and printed circuit boards. Waste is defined as the materials destined for landfill or incineration. The cost of waste treatment of components in this category ranges from 0-100 Euros / ton. Chemical waste (or special waste) requires special processing, which costs > 200 Euros / ton.

---

[10] Billatos, Samir B.; Green Technology and Design for the Environment; University of Connecticut; Storrs, C T; Taylor and Francis, 1997
[11] www.spectracode.com/index2.html
[12] Burall, Paul; Product development and the environment, The Design Council; Gower; 1996
[13] Graedel, T.E; Allenby, B.R.; Design for environment, AT&T Bell Laboratories, Prentice Hall, 1996

1.2.8.3 European Directive on waste

The proposed European Directive on waste from electrical and electronic equipment, November 1998, says that member states shall take necessary measures to ensure that, no later than 1 January 2004, the following targets are attained by producers (here we mention only the product groups in the scope of this research):

- for all separately collected end-of-life televisions, the rate of recycling shall reach a minimum of 70% by weight of the appliance
- for all separately collected end-of-life washing machines, the rate of recycling shall reach a minimum of 90% by weight of the appliance
- for all separately collected end-of-life computers, the rate of recycling shall reach a minimum of 70% by weight of the appliance (including CPU, mouse, screen and keyboard)
- for all separately collected end-of-life coffee-makers, the rate of recycling shall reach a minimum of 70% by weight of the appliance.

For plastics, the European Directive says that member states shall ensure that recycled plastics in new electrical and electronic equipment make up at least 5% of the total plastic content by 1 January 2004.

1.2.9 Specific reprocessing of components

Disassembled and categorised components are recycled in specific reprocessing centres, whose output is made to suit the specifications of buyers (the raw material industry). Markets for disassembled components are as follows:

- electronic components (printed circuit boards, coils, internal wiring) are supplied to a special reprocessing centre in order to retrieve the precious metals, copper, and ferrous metal
- glass components are supplied to the glass recycling industry or to the ceramic industry
- large ferrous components are supplied to the shredder for cars
- large aluminium components are supplied to an aluminium smelter
- plastic components can be supplied to a plastic reprocessing centre, where the plastics are reduced and regranulated.

The recycling route determines whether the material is recycled to a high or low grade (see below).

DEFINITION: Recycling grade

‘The quality level at which the original materials are recovered. In high-grade material recycling, the original materials are recovered in their original quality. In low-grade material recycling, the original materials are recycled to a lower quality level. This option often applies for contaminated materials. In alternative material recycling, the materials are recycled into entirely new materials. For instance, if the back panel consists of mixed plastics, ‘back to the monomer’ processes can be applied to recover the original ingredients (the monomers) from which new kinds of plastics can be reduced.’[3]

In high-grade recycling, the picture tube glass from a television set is re-used in the production of picture tubes, but in low-grade recycling it goes towards the production of ceramics.

1.3 Recycling practice

Until now, most of the efforts concerning recycling of household appliances have been devoted to refrigerators and freezers. Recycling of cars is currently practised in Germany and Japan, and many German-built cars already use recycled plastic materials.[4] Recycling photocopiers involves mainly re-using valuable components in new ones. The recycling of household appliances is being developed due to the introduction of disposal regulations.

1.3.1 International recycling practice of household appliances

As part of this project, in February 1999 Consumentenbond carried out a small survey to investigate, among other things, the current state of play on recycling in the countries involved in the project. The result, and information from other sources, follow.

Pilot recycling projects have been carried out in Austria, Germany, the Netherlands and the United States. Current recycling practice in Australia is focused on mechanical recycling, the scrap metal being exported to Korea.[14] Germany has a number of recycling factories for discarded refrigerators.[4] In the Netherlands, two recycling centres (Coolrec, Mirec) recycle the current waste output of white and brown goods. In the United States, there are quite a few privately owned centres specially designed for recycling; these are generally regional, and have contracts with organisations or institutions which take in large numbers of products (such as municipal or county-based waste hauliers or companies).[15] In the United Kingdom, a major waste management company (UK Waste) and an electronics recovery firm (R. Frazier) are working together to offer a national electronics waste recovery service. Many of the collected items will be used as complete systems or disassembled to provide components rather than being scrapped and reprocessed.[16] In Japan, the pioneering company Matsushita Electric has produced a washing machine that can be disassembled with a screwdriver alone.[4]

1.3.2 Recycling scenarios

As mentioned within the discussion of the phases of the recycling process, above, the current possible recycling scenarios are:

1. mechanical recycling

2. component recycling in which some components are re-used and others are specifically recycled and / or incinerated

3. component recycling in which components are specifically recycled, and others may be incinerated.

The case studies product groups – washing machines, computers and televisions – are a model for possible recycling scenarios. Each group follows one of the three recycling scenarios. Table 1 shows the current recycling scenarios for each product group represented.

Table 1. Recycling scenarios for case study product groups

Product group	Recycling scenario	Disassembly	Case study
Coffee-makers	Mechanical recycling	No	No
Washing machines	Mechanical recycling	No	Yes
Computers	Component recycling, re-use of components	Optimal disassembly	Yes
Televisions	Component recycling, specific recycling	High disassembly degree	Yes

[14] Sustainable Consumption Questionnaire response, Australian Consumers' Association, 1999
[15] Sustainable Consumption, Questionnaire response, Consumers' Union of the US, 1999
[16] Sustainable Consumption Questionnaire response, Consumers' Association (UK), 1999
[17] TNO MEP experience

Ideally, washing machines are mechanically recycled in a metal shredder, or disassembled when this is not economically viable.[17]

Computers contain valuable processors and memory chips, so component recycling is preferred for computers, with some components re-used and others specifically recycled. This scenario is currently practised on a small scale, the disassembly process being the main obstacle for increasing the scale. That is why, for the case study on computers, attention is given to optimal disassembly.

Unlike computers, televisions do not contain valuable components. A television contains components with several materials that cannot enter mechanical recycling. The recycling scenario for televisions is component recycling, in which components are specifically recycled.

Mechanical recycling is preferable for coffee makers. Due to the low weight of components, disassembly is not financially viable at present.

1.4 Assessment categories for recycling

The recycling process flowchart (Figure 1) was designed to develop assessment categories of recyclability. For each assessment category, criteria are then developed. On the basis of this flowchart, the following assessment aspects are considered:

1. information to consumers
2. environmentally harmful substances
3. recycling.

The assessment categories ‘environmentally harmful substances’ and ‘recycling’ consist of criteria that are different for each case study product group. As mentioned, the case study product groups demonstrate the different recycling scenarios for household appliances. The ‘recycling’ assessment consists of criteria for disassembly in cases of component recycling. For ‘specific recycling’ and ‘re-use’ purposes, disassembly of the critical and / or valuable components is of particular importance. For the scenario of mechanic recycling, it is preferable not to have to disassemble components containing environmentally harmful substances. This is discussed in more detail in the case studies.

2 Case studies

Set out in this section are case histories based on washing machines (demonstrating mechanical recycling), computers (demonstrating optimal disassembly) and TVs.

2.1 Washing machines: case study on mechanical recycling

This case study is based on a review of the literature on the current recycling scenario for washing machines. It considers which components have environmentally harmful substances, which components can eventually be disassembled and collected, and what conditions are necessary for high-grade mechanical recycling.

2.1.1 Constituents of washing machines

Front-loading washing machines consist mainly of ferrous components (65%), concrete blocks (19.5%), plastics (6%), and non-ferrous components (3%).[18] Recycling of washing machines mainly involves recovering ferrous material. Compared with other white goods, washing machines contain the least amount of metals due to the concrete contra weights. Table 2 shows the main components and materials of washing machines.

2.1.2 Current recycling scenario for washing machines

The current recycling scenario is mechanical recycling after compulsory disassembly of environmentally harmful capacitors, i.e. capacitors containing polychlorobiphenyls.

In principle, an entire washing machine can be supplied to a large shredder, after which the different materials are separated from the mixed material output, but at present capacitors are compulsory removed before the rest of the machine is mechanically recycled.

2.1.2.1 Components containing environmentally harmful substances

Capacitors in washing machines can contain polychlorobiphenyls. According to the

Table 2. Main components of washing machines

Main components[19]	Weight (1)[18] kg	Main materials[18]
Housing / console / fuselage	19.1	Ferrous metal, plastics, glass
Barrel / contra weight / drive mechanism	22.6	Ferrous metal, concrete, rubber
Washing drum / pump	19.4	Ferrous metal
Electric components: timer, electric motor, printed circuit boards, wiring	1.6	Copper, ferrous metal, plastic
Water tubes	1.5	Plastic
External cable	0.1	Copper, plastic

(1) = average weight of component

[18] Ploos van Amstel Milieu Consulting, Apparetour, Nationaal proefproject inzameling en herverwerking wit-en bruingoed in de regio Eindhoven, Deelrapport technologie, 1997
[19] Montage und Demontage; Aspecte erfolgreicher Product Konstruction; VDI berichte 999; 1992

Apparetour study, 76% of washing machines currently discarded contain a capacitor, and 19% of washing machines have a capacitor containing polychlorobiphenyl.[18] Discovering whether a washing machine has an environmentally harmful capacitor is not possible simply by knowing the make or model, so the capacitor has to be removed from all washing machines to check visually whether it is environmentally harmful.

According to the Apparetour study, capacitors made after 1984 are free of polychlorobiphenyls.[18] This means that it will not be until 2015 that all washing machines suspected of containing polychlorobiphenyls will have been discarded and recycled. It also means that no environmentally harmful capacitors will be found when testing new washing machines.

The non-metal materials go for landfill or incineration for energy recovery. Components which contain these non-metal materials have to be clean for incineration, i.e. the materials have to be free of chlorides and flame retardants, in order to avoid harmful emissions of noxious compounds.

2.1.2.2 Disassembly of components

Washing machines contain contra weights, which are often concrete blocks. According to the Apparetour study, some of the concrete from washing machines can end up in the ferrous part (because it has some magnetic properties. This will then be contaminated, and therefore either unmarketable or less marketable, depending on the amount of concrete.[18] However, the current practice is that washing machines with concrete blocks are supplied to the shredder, after which the concrete is separated from the ferrous part. In principle, if the concrete block was easy to disassemble, it would be suitable for mechanical recycling, but this does not happen in practice. Even better would be the disassembly of the concrete block before (long distance) transport to a recycling centre. If the printed circuit board is easy to disassemble, it is, in principle, better to use high-grade recycling of the metals of this component, but this does not happen in practice.

Washing machine components can be disassembled as follows:

- removal of external cables
- removal of part of the housing in order to get access to components
- removal of capacitors
- removal of concrete blocks, if disassembly time is short
- removal of printed circuit board, if disassembly time is short
- removal of the motor
- mechanical recycling of remaining components.

2.1.2.3 Collection of components made of the same material

This phase only applies to:

- collection of electronic components: printed circuit boards
- collection of concrete blocks, delivered to reprocessors of building and scrap waste
- collection of external cables, delivered to the cable reprocessing industry.

2.1.2.4 Mechanical recycling of washing machines

According to the Apparetour study, it is more profitable to send large white goods to the white goods shredder than to the larger shredder for cars. Heavy iron and aluminium parts have to be removed before washing machines can be supplied to the white goods shredder. Current recycling practice is that, as mentioned, complete washing machines are supplied to the metal shredder installation after compulsory disassembly of the capacitors. Mechanical recycling of washing machines is used because disassembly is uneconomic.[17]

Attaining a high recycling rate is problematic if the metal plates of housings are laminated rather than pure. Laminated metal is generally difficult and uneconomical to recover, and tends to be discarded.[13]

2.2 Computers: case study on optimal disassembly

Computers are a special product group: they have a relatively short life span due to the fast development of hardware and software, and world-wide sales have increased dramatically in the past decade. Recycling of computers is of increasing interest because of the sheer numbers that will be disposed of in the future, the value of their components, and the potential for plastic recycling.

This case study is based on a literature review. It first describes the current recycling scenario for computers, then lists the environmentally harmful substances that computer components may contain – and which are valuable. The disassembly sequence of the system unit is discussed next. Finally, it explores the design improvements that would achieve optimal disassembly.

2.2.1 Constituents of computers

This case study concerns personal computers, the basic components of which are a keyboard, system unit (containing, among other things, the motherboard and memory chips), and a monitor. Portable computers do not fall within this product group. The components and materials of computers are represented in Table 3.[20]

2.2.2 Current recycling scenario for computers

The recycling scenario for computers is partial disassembly of valuable components destined for re-use, and recycling and / or incineration of the remainder.

Re-use of components is currently practised on a small scale. Processors and memory chips are separated from discarded computers and re-used in toys. The other current recycling practice is division of the basic components of computers into two categories of household appliances: the monitor goes with brown goods that contain a picture tube, and the keyboard and system unit go with electrical and electronic equipment that does not.[21] The televisions case study also covers the recycling of computer monitors. In general, electrical equipment without a picture tube is mechanically recycled in bulk, unlike monitors and televisions, where component recycling is applied. The keyboard and mouse are treated as waste to be incinerated. This case study is concerned mainly with the system unit.

2.2.2.1 Mechanical recycling

System units of computers are currently recycled mechanically in bulk, unlike monitors and televisions. The processing takes place in the same installation and, generally, the same specific way as the disassembled electronic components of televisions.[21] Mechanical recycling of computer system units is difficult because of the amount of plastic that needs to be separated from more valuable materials.[18]

2.2.2.2 Components containing environmentally harmful substances

According to the Apparetour study, there is an 8.4% chance that a computer will contain a

Table 3. Components and materials in personal computers (picture tube, system casing and keyboard)[20]

Main components	**Weight** %	**Main materials**
Housing and construction	50-60	Ferrous metals, plastics (ABS, PS / SBR, PP)
Picture tube assembly	20-30	Glass containing lead and barium oxide, iron, copper, plastics
Printed circuit boards and electronics	10-20	Epoxy resin / cardboard or thermoplastic with various materials
Wiring	1-5	Copper, PVC, other flame retardant plastics
Other components	1-5	Steel, nylon, PVC, various
Remaining materials	1-5	Copper, zinc, aluminium, iron, magnetic material, plastics
Total weight	15-25 kg	

[20] The data are based upon an interpretation of existing PCs, including picture tube and keyboard
[21] Ploos van Amstel Milieu Consulting, Back to the beginning, National pilot project for collecting, recycling and repairing electrical and electronic equipment in the district of Eindhoven, Apparetour, September 1997

battery. However, these are mainly alkaline, consisting of substances less harmful than NiCad batteries. A very small number of computers (1.7%) contain a display with possibly harmful substances. The amount of lead and cadmium found in electronic and plastic components is controlled by national legislation.

Brominated flame retardants are used in the housing and in printed circuit boards. Housings which are free of brominated flame retardants are feasible because there are brands on the market that have such housings. Printed circuit boards which are free of brominated flame retardants are not yet feasible for all manufacturers: at present, only one manufacturer has this technology.[22] These issues are further discussed in the case study on televisions.

2.2.2.3 Component recycling

The other recycling scenario, which is practised on a small scale, is component recycling for re-use of valuable components. The system unit contains the following valuable components:

- power supply
- memory cards
- printed circuit boards (more valuable than those of televisions)
- hard drive
- floppy disk drive.

Currently, memory cards are re-used, on a small scale, in toys.

The disassembly sequence for the system unit is:

- removal of external cables
- removal of top housing
- removal of electrical connections (wiring and connectors)
- removal of speaker
- removal of drives subassembly
- removal of the power supply
- removal of I / O cards
- removal of hard drive
- removal of floppy disk drive.

2.2.2.4 Potential specific recycling of components

Computers have a potential for component recycling. The most valuable components of the system unit are electronic components, which can undergo specific recycling in the same way as the electronic components of televisions. Besides the valuable electronic components, computers contain plastic in abundance. Computers are a prime candidate for recycling of plastics.

2.2.3 Optimal disassembly

Optimal disassembly is an important issue for computers. It means that the appliance is disassembled until the most valuable components are removed, and the remainder is recycled and / or incinerated. This implies that the most valuable components should be easy to disassemble, keeping disassembly costs as low as possible.

2.2.3.1 Design improvements

Computers differ from many other products in that they are designed to be customised. In general, a system unit has a modular design; however, screws and cable connectors are used extensively, many of them unnecessarily. To attain optimal disassembly, the design must be improved to eliminate them.[9]

Another hindrance for optimal disassembly is the long disassembly time of plastics. In the Apparetour study, the criterion setting for the disassembly time of plastic components, which are composed as much as possible of one single material, was 2 minutes per kg. In their disassembly test, the disassembly time of 2.7 minutes per kg was evaluated as too long.[21]

2.3 Televisions: case study on component recycling

This case study covers colour televisions. It includes descriptions of the constituents of televisions and the current recycling scenario for them.

[22] Atlantic Consulting, Draft criteria (version 1.2), EU Ecolabels for personal computers, April 1998

Table 4. Disassembled parts in new picture-tube-holding brown goods [18]

Main components	Weight %	Main materials[2]
External cables	0.2	Copper, PVC, flame retardant plastics
Back and front panel	15.9	PS, PS-FR, (sometimes PP-FR, ABS-FR)
Environmentally harmful electronic components	8	Epoxy resin / cardboard, copper, plastics, environmentally harmful substances
Deflection units	2.6	Copper, plastic
Copper degaussing coil	0.6	Copper, plastic
Aluminium degaussing coil	0.3	Aluminium, plastic
Picture tube, glass recycling route	62.2	Glass containing lead and barium oxide
Ferrous part	5.3	Ferrous metals
Various	4.3	Various materials

2.3.1 Constituents of televisions

Televisions weigh approximately 10-40 kg, depending on the diameter of the picture tube (37-70 cm). The materials and components in small and large televisions are similar. Table 3 shows the disassembled parts of 781 new picture-tube-holding brown goods from the Apparetour pilot project.[23] The majority (82%) of this category of goods are televisions.

2.3.2 Current recycling scenario for televisions

The current recycling scenario for televisions is component recycling with specific recycling of components. Component recycling has to be applied because a television consists of components of different materials that require specific reprocessing. Mechanical recycling is not advisable for televisions.

2.3.2.1 Components containing environmentally harmful substances

In old televisions, for which the average production year was 1975, the environmentally harmful components are:

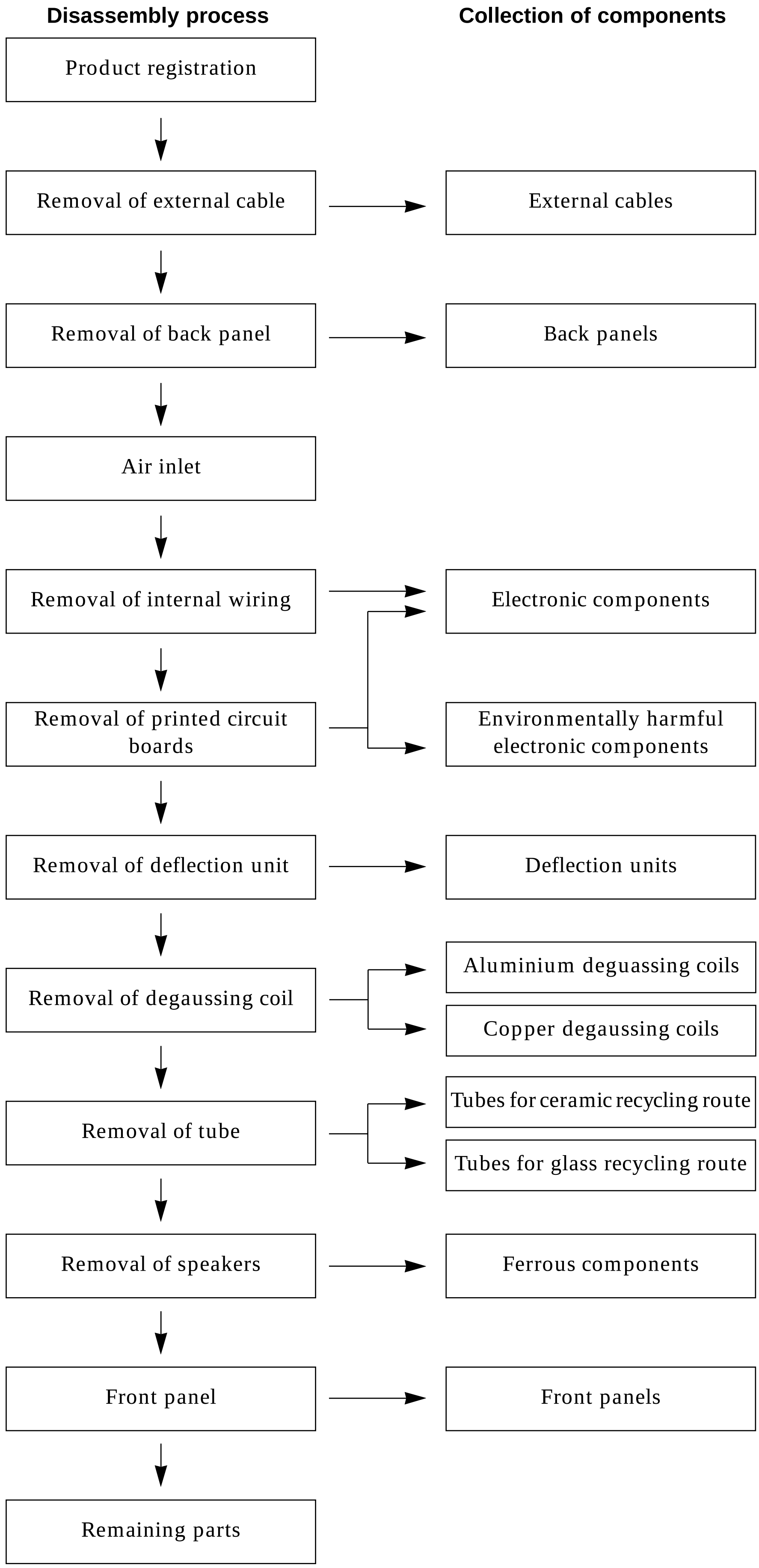
- rechargeable batteries
- electrolytic capacitors with a minimal length of 3 cm which contain polychlorobiphenyl.

According to the Apparetour study, these environmentally harmful components are not found in new televisions.[18] It is safe to assume that capacitors containing polychlorobiphenyl have been phased out. However, cadmium was still found (at 115 ppm) in the electronics. The amount of lead found in the electronics (1.5%) comes mainly from solder. According to the results of the analysis in the Apparetour project, it appears that disassembly of components with environmentally harmful substances has virtually no effect on the concentration of cadmium and lead in the electronics. Considering the concentration of cadmium, there must be other sources in new televisions. This means that besides investigating the environmentally harmful components, the percentage weight of environmentally harmful substances of components destined for recycling must be considered. This also concerns the tube, which must be free of cadmium.[24]

Many televisions have back panels and printed circuit boards which contain bromine- and chlorine-containing halogenated flame retardants.[25] Incineration will yield noxious compounds, and potential recycling is not possible. For halogenated flame retardants in back panels, alternatives are feasible for manufacturers.

[23] The average production year of new picture-tube-holding brown goods, and thus also for new televisions, was 1995
[24] Karstadt AG, Umweltgerechte produkgestaltung, Leitladen für die artikelgruppe Rundfunk/Fernsehen, juli 1998
[25] Chemielinco, Environmental aspects of 36-cm colour TVs, projectnumber 94442, 1995

Figure 3. Disassembly process for televisions currently applied in Dutch recycling facilities



2.3.2.2 Disassembly of main components

The flowchart of the disassembly process for televisions is illustrated in Figure 3.[21] On a disassembly line for tube-holding brown goods, a television is disassembled in the following sequence:

1. removal of external cables
2. removal of the back panel
3. air inlet (for safety considerations air is let in the tube at the high voltage anode lead, in order to avoid possible implosion of the vacuum tube)
4. removal of internal wiring
5. removal of printed circuit boards
6. removal of the deflection unit
7. removal of the degaussing coil (the cable wound around the picture tube near its face, used to degauss the picture tube for a few seconds when the receiver is turned on)
8. removal of the tube
9. removal of the speakers in the front panel or housing.

What remains is the front panel or the housing and any other components.

2.3.2.3 Collection of components made of the same materials

The manually disassembled components of televisions are collected in several main streams, which are further recycled at specific reprocessing centres:

- electronic components with environmentally harmful substances (electrolytic capacitors and rechargeable batteries), to be processed further as chemical waste

- electronic components (printed circuit boards, transformer, deflection units, internal wiring), which are further reprocessed depending on their materials: ferrous metals, aluminium, copper / precious metal concentrate, and plastics

- colour picture tubes for the glass recycling route or the ceramic recycling route: the tube glass is secondary raw material for tube glass production or raw material for the ceramic industry

- back panels and front panels, and plastic / metal combinations, usually for incineration

- other parts: housings made of wood fibre (landfill or incineration), disassembled ferrous components (delivered to a blast furnace), degaussing coils and external cables (delivered to the cable processing industry), and the remainder which, depending on its composition, is transported to landfill sites or municipal waste incinerators.

Specific reprocessing of components

The disassembled components are reprocessed to meet the specifications of buyers. These specifications vary: acceptance of disassembled components depends on the buyer’s own processing conditions. The recycling route that the collected components undergo is what determines their recycling grade.

Tubes are low-grade recycled through the ceramic recycling route, and high-grade recycled if the tube glass is to be secondary raw material for tube glass production. In this latter (tube-glass) recycling route, glass containing lead and barium oxide is separated from the delivered tubes. Lead glass goes into glass production of the neck and conus of picture tubes; barium glass goes into glass production for screens. Harmful fluorescent powders are compulsorily separated from the delivered tubes.

Metals from electronic components are high-grade recycled.

The current practice is that back panels and front panels are not recycled but incinerated or sent to landfill sites.

2.4 Assessment method for recyclability

This describes the steps to be taken to assess the recyclability of household appliances. The assessment method is presented in Figure 4.

The results of this process are the assessment criteria, the rating of the criteria, and the

weighting of the assessment categories. This method was used for televisions. A pilot disassembly test was carried out for televisions (see Appendix 3A).

Firstly, the current recycling scenario of the product group is determined, in order to acquire the assessment criteria. The recycling scenario determines the type of checklist to be used - the one for mechanical recycling or the one for component recycling. The next phase is drawing up a disassembly form, followed by product research and determination of the critical variables, in order to rate the assessment criteria. Then a standard product is defined. The final phase is a sensitivity analysis in order to weight the assessment categories.

The weighting of the assessment categories was done for televisions using DFE (Design For Environment), a software tool of TNO Institute of Industrial Technology.1 It was developed for designers, and enables them to make a financial and environmental end-of-life evaluation of a prototype.

2.4.1 Pilot research project on televisions

The recyclability assessment method was carried out for televisions in a pilot research project.

2.4.1.1 Recycling scenario for televisions

The component recycling scenario applies to televisions. In the pilot research project on televisions, a checklist for component recycling was developed. This appears in ‘Guidelines for recyclability’ (section 3).

2.4.1.2 Drawing up a disassembly form

A disassembly form was devised to record the results of the disassembly test. The form is an Excel program, so data can be recorded using a laptop. The disassembly form consisted of two parts: one part to record the results of the

Figure 4. Assessment method for recyclability

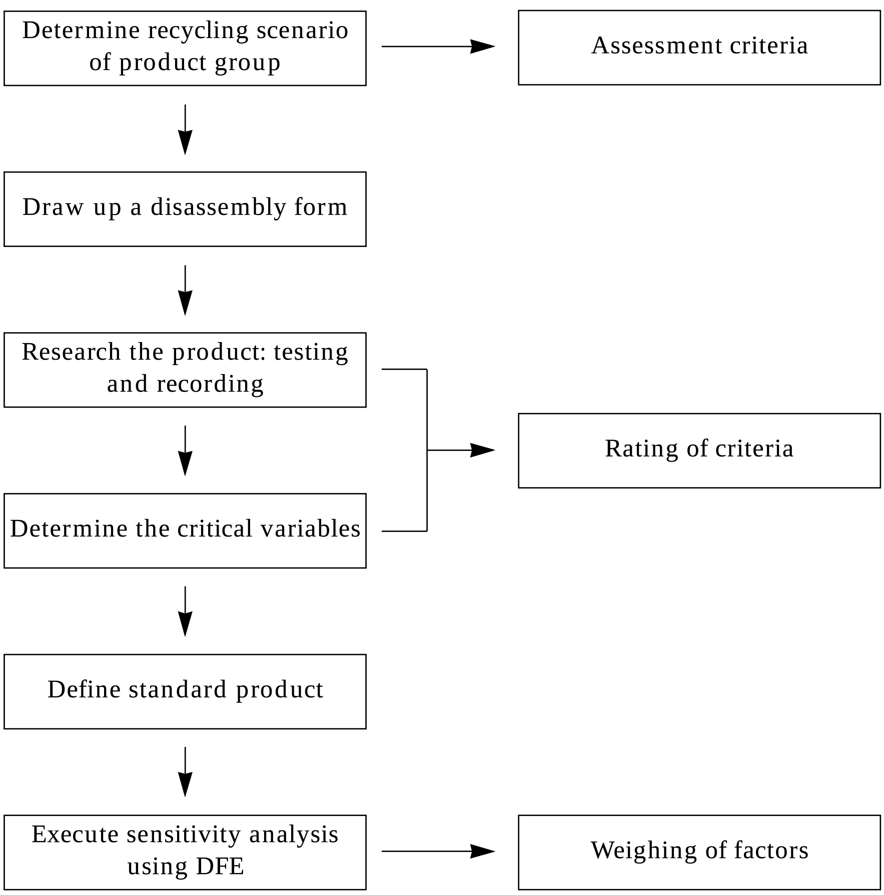


Table 5. Sensitivity matrix

Assessment categories		Recycling percentage kg	Financial impact Euro	Environmental impact MET (5)
Information to consumers		x	x	x
Environmentally harmful substances		x	x	x
Disassembly	Total (1)	0	++	0
	Back panel (2)	0	+	0
Material recycling	Back panel (3)	++	++	++
	Tube (4)	0	- -	++

(1) = optimal design versus bad design
(2) = short disassembly time versus longest
(3) = recycling versus incineration
(4) = glass recycling route versus ceramic recycling route
(5) = MET is a measure in which material use, energy use and toxic substances are expressed in one value Key
x = not studied
\+ = benefit
\- = loss
\- - = large loss
0 = no influence

disassembly test, and one part to be filled in after disassembly with an inventory of all components.

For each disassembled component, the disassembly form has space for the name of the component, the disassembly time, type of connections, the amount of connections of one type, necessary tools, obligatory precedence of components to disassemble, and final remarks. The connection types and tools are letter-coded.

The disassembly form had three columns, where the difficulty of disassembly – namely obstruction, required precision and force – could be recorded with a 0 (= low), 1 (= medium), or 2 (= high). This rating proved to be relative, so it was omitted from the final set of criteria (difficulty of disassembly is, in any case, covered by the recorded disassembly time).

The part of the disassembly form to be filled in after disassembly of the appliance is for recording the inventory of all components. The weight of each component is recorded. Then the percentage weights of the materials of which the component consists are estimated. Any labels and their content are recorded. Finally, the disassembly form has a column in which to record whether the component is categorised as valuable, waste, or chemical waste.

2.4.1.3 Product research: testing and recording

Two people are needed to carry out the disassembly test: one to record and one who is an experienced disassembler. Alternatively, one person can do the test, combining disassembly and recording. However, we prefer an experienced disassembler to do the disassembly part.

The pilot disassembly test consists, in principle, of measuring the time to fulfil a disassembly step of each component until all components are disassembled, and an inventory of the components.

For the pilot disassembly test, four televisions were chosen: two were new televisions from the latest test, the other two were old sets from a collection and disassembly centre. The requirements for the disassembly test are discussed in Appendix 3C.

2.4.1.4 Determining the critical variables

The critical components whose disassembly time varies the most between the investigated televisions are, in order of magnitude:

1. back panel
2. deflection unit
3. internal wiring
4. main printed circuit board.

These components are not necessarily the components with the longest average disassembly time, but the components whose disassembly times vary the most. Rating of the criteria is based on the deviation within the product group.

2.4.1.5 Defining a standard television

For information about this, see Appendix 3A, ‘Pilot research project for televisions’.

2.4.1.6 Sensitivity analysis

A sensitivity analysis was carried out in order to be able to prioritise the different assessment aspects. Priority setting was established with the help of the computer-aided recovery analysis tool Design For Environment (DFE). The results of the sensitivity analysis are shown in Table 5.

2.4.1.9 Weighting of the assessment categories

This is based on the sensitivity analysis. First, an arbitrary proportion for the first two categories – namely ‘information to consumers’ and ‘environmentally harmful substances’ – was set at 20%. In this way the recycling proportion is emphasised. The ratio between recycling and the first two assessment categories is thus 60-40%. Priority-setting within the sub-categories of recycling was done by the sensitivity analysis. For televisions, material recycling has a large impact (benefit) on recycling percentage as well as on financial and environmental impact, while disassembly influences only the financial impact. For this reason, the ratio between disassembly and material recycling was set at 1 : 2. In conclusion, the recyclability weighting of televisions is 20% each for information to consumers, environmentally harmful substances and disassembly, and 40% for material recycling.

3 Guidelines for recyclability

3.1 Checklists for assessing recyclability

The methodology for the recyclability assessment of household appliances was developed with three case study product groups. Checklists were developed for two possible scenarios:

- mechanical recycling (Table 6)
- component recycling (Table 7).

The classification of the criteria in the checklist is based on the different phases of the recycling process. For each phase, the checklist contains the criteria and the corresponding research method of assessing them (see also Figure 2 for the stages in the recycling process). The checklist and guidelines were developed as part of this project.

3.2 General guidelines for recyclability

General guidelines were developed for the criteria in the mechanical and component recycling checklists. The following guidelines are based on the checklist for component recycling, and contain key questions, assessment criteria and the research methods used to assess them. The rating and weighting of the criteria are proposals by Consumentenbond. Specific guidelines developed for televisions are presented in Appendix 3B.

It is very important to realise that what the guidelines contain are proposals for weighting and rating the relevant criteria for recycling. The local situation, such as intake logistics and treatment methods for white and brown goods waste, may influence the weighting and rating of criteria.

3.2.1 Key questions, assessment criteria and research methods

3.2.1.1 Discarding the appliance

KEY QUESTION
Does the user manual give information to consumers on how and where to dispose of the old appliance so it can be collected for recycling?

ASSESSMENT: User manual
The assessment of recycling information to consumers, consumer organisations and recycling plants in the user manual or other sources of information consists of the following criteria:

- information about how and where consumers can dispose of the appliance
- recycling guarantee: does it mention whether a recycling guarantee is given when a new system is bought?
- information about avoiding heavy metals like cadmium, as well as harmful materials like PVC, CFCs, and halogenated flame retardants
- information about location of components with environmentally harmful substances
- full information about the different electrical and electronic components and materials

Table 6. Mechanical recycling checklist (stages, criteria, research methods)[26]

Stage	Criteria	Research method
Discarding the appliance	• Information about how and where to dispose • Recycling guarantee • Information about what electronic components and materials are used in the appliance • Information about avoiding harmful materials • Information about location of components with environmentally harmful substances	Product inventory
Components with environmentally harmful substances	• Do components contain cadmium or other hazardous heavy metals? • Do components contain chlorine? • Do the electronics contain cadmium or other heavy metals?	Product inventory
	• Do housing and printed circuit boards contain halogenated flame retardants?	Halogenated flame retardants determination by pyrolysis mass-spectrometry
	• Material labelling percentage: % of components with environmentally harmful substances labelled	Product inventory
	• Are labels correct?	Product inventory
Disassembly of environmentally harmful components, of components that may interfere with recycling	• Total disassembly time • Type of connections • Diversity of connection types • Number of connections of one type	Laboratory disassembly test
	• Number of necessary tools • Special or non-universal tools • Safety of disassembly	Component inventory during disassembly test
Mechanical recycling: material outcome	• Percentage weight of valuable materials • Percentage weight of harmful materials • Percentage weight of waste materials • Is the metal of the housing laminated?	Component inventory after disassembly test

[26] This checklist was developed by the Consumentenbond in co-operation with TNO Institute of Industrial Technology

Table 7. Component recycling checklist (stages, criteria, research methods)[26]

Stage	Criteria	Research method
Discarding the appliance	• Information about how and where to dispose of it • Recycling guarantee • Information about what electronic components and materials are used in the appliance • Information about avoiding harmful materials • Information about location of components with environmentally harmful substances	Product inventory
Components with environmentally harmful substances	• Are there any rechargeable batteries? • Do components contain cadmium or other heavy metals? • Do the electronics contain cadmium?	Product inventory
	• Do the housing and the printed circuit boards contain halogenated flame retardants?	Halogenated flame retardants determination by pyrolysis mass-spectrometry
	• Material labelling percentage: % of components with environmentally harmful substances labelled	Product inventory
	• Are labels correct?	Product inventory
Disassembly into main components	• Total disassembly time • Disassembly time of critical components • Type of connections	Laboratory disassembly test
	• Diversity of connection types • Number of necessary tools • Special or non-universal tools • Safety of disassembly	Component inventory during disassembly test
Collection of components with the same materials: material categorisation and labelling	• Percentage weight of valuable materials • Percentage weight of harmful materials • Percentage weight of waste materials • Material labelling percentage: % of plastic parts > 25g labelled • Are labels correct (according to ISO 11469)?	Component inventory after disassembly test
Specific recycling of components	• Suitability for high- grade recycling	Component inventory after disassembly test
	• Diversity of incompatible materials used in component • Are parts of components with different incompatible materials separable?	Plastic determination by Sink / float-behaviour and fire properties

used in the appliance available for the recycling plant (eg a microchip containing this information in the appliance)

Evaluation of information on recycling in the user manual:
(- -) No information to consumers in the manual on recycling of the appliance
(-) General information about disposal of appliance
(#) Information on disposal addresses, disposal of batteries, type of waste
(+) Recycling guarantee, and information about location of environmentally harmful components
(++) Full information about the different electronic components and materials.

RESEARCH METHOD
The research method for data collection of information to consumers is by product inventory.

3.2.1.2 Components containing environmentally harmful substances

KEY QUESTIONS
1. Are there any components containing environmentally harmful substances in the appliance?
2. Are components containing environmen tally harmful substances identifiable and labelled?
3. Are components containing environmentally harmful substances easy to disassemble?

ASSESSMENT: Environmentally harmful components
Components containing environmentally harmful substances are assessed according to the European Directive on waste from electrical and electronic equipment.

The assessment is based on the following criteria:

- Are there any rechargeable batteries?

- Do components contain cadmium, lead or other harmful heavy metals?

- Do plastic components or printed circuit boards contain halogenated flame retardants?

- Material labelling percentage: % of components with environmentally harmful substances labelled

- Are labels correct?

Rating of cadmium in components of the appliance[27]:
(- -) Component contains Cd in > 50 mg / kg
(-) Component contains Cd in < 50 mg / kg
(++) Component contains no Cd
Break factor: if not in compliance with national legislation, then evaluation

Rating of other heavy metals can be based on national legislation. We propose to use a five-point rating scale as follows:
(- -) Concentration > twice threshold value in legislation
(-) Threshold value < concentration < twice threshold value in legislation
(#) Threshold value <concentration < half threshold value
(+) Half threshold value < concentration < detection limit
(++) Concentration < detection limit
The overall assessment can be based on the worst heavy metal present in the sample.

Rating of halogenated flame retardants in plastic components (in %w / w):
(- -) Back panel contains bromine > 1 w / w %
(-) Back panel contains bromine in < 1 w / w %
(++) Back panel contains no bromine

Rating of the percentage of labels on components with environmentally harmful substances:
(- -) No labels found
(-) 20-60%
(#) 60-80%
(+) 80-100%
(++) 100%

Rating of the accuracy of each label*:
(- -) Label not correct
(#) Label correct, minimal requirements
(++) Maximal requirements

[27] According to the Dutch Environmental Act: Wet milieubeheer, Besluit Aanwijzing Gevaarlijke Afvalstoffen

* If more than one label is found, this assessment is applied to each label

RESEARCH METHODS

The research method for data collection on rechargeable batteries is by product inventory.

The research method for data collection on halogenated flame retardants is carried out subsequently, as follows:

1. Screening for presence of halogens (CL, Br) by the Beilstein test
2. If halogens are present, determination of amount (if any) of bromine (Br), antimony (Sb), by instrumental neutron activation analysis (INAA) or ICP-MS
3. If bromine is present, identification of flame retardants by pyrolysis mass-spectrometry.

The research method for data collection of cadmium is by determination of percentage weights of cadmium (Cd) through instrumental neutron activation analysis (INAA) or ICP-MS.

The research method for data collection on labelling is by product inventory.

3.2.1.3 Disassembly into main components

KEY QUESTIONS

1. Is the appliance designed for disassembly?
2. For which components is disassembly difficult?
3. Can the appliance be disassembled with universal tools?

ASSESSMENT: Disassembly

The total disassembly time is, in principle, the most important criterion. Critical components are those whose disassembly time differs greatly from model to model: they are the components for which disassembly can be difficult.

The criteria for disassembly are:

- disassembly time
- diversity of connection types
- number of necessary tools
- special or non-universal tools
- safety of disassembly.

For each of these disassembly criteria, the rating can be based on the differences found in the product test; a rating on a 3- or 5-point scale can normally be applied. An example for televisions is given in Appendix 3B.

Rating of number of necessary tools:

(- -) > 2 required for a disassembly operation
(-) More tools required than amount of disassembly operations
(#) 2 tools; requiring both hands for one disassembly operation
(+) 1 tool required per disassembly operation
(++) 1 tool required for all disassembly operations

Rating of special or non-universal tools:

(- -) Drill, grinding wheel, hacksaw, power sabre saw
(-) Gripping and fastening tools
(#) Fixed-end wrench, adjustable wrench
(+) Torcx screwdriver, socket with ratchet
(++) Universal tools are: flat-head screwdriver, cross-head screwdriver

The rating of safety of disassembly depends on the possible risks. An example for televisions is given in Appendix 3B.

RESEARCH METHOD

The research method for data collection of disassembly is by a laboratory disassembly test and product examination. In the laboratory disassembly test, the appliance is fully disassembled into its main components. These components are mentioned in the disassembly guidelines for each product group. The disassembly sequence is also mentioned, although this may be varied during the disassembly test. The aim of the disassembly test is to record the time taken to perform standard disassembly actions and to record data. The collected data are recorded in a standard disassembly spreadsheet.

3.2.1.4 Collection of components of the same material: material choice and labelling

KEY QUESTIONS

1. What percentage of the material has reprocessing potential?
2. What is the percentage weight of components categorised as valuable, waste, chemical waste?
3. Are materials labelled as to their content?

ASSESSMENT: Collection of components

The assessment of material choice and labelling is on the following criteria:

- percentage weight of components with valuable materials
- percentage weight of components categorised as waste
- percentage weight of components with environmentally harmful substances
- material labelling percentage: % of plastic parts > 25g labelled
- are labels correct (according to ISO 11469)?

The rating of percentage weight of components with valuable materials, waste, and environmentally harmful substances is based on an expert judgement, and depends of the type of appliance. An example for televisions is given in Appendix 3B.

Rating of percentage of labels identifying material on plastic parts > 25g:

(- -) No labels found
(-) 20-60%
(#) 60-80%
(+) 80-100%
(++) 100%

Rating of correct labels on plastic (according to ISO 11469)*:

(- -) Material abbreviation not correct
(#) Abbreviations for materials and harmful substances (halogenated flame retardants) correct
(++) Date of manufacture, trade name, company name, component registration number added

* If more than one label is found, this assessment is applied to each label

RESEARCH METHOD

The research method for data collection of material choice and labelling is by product examination and material analysis of disassembled components.

3.2.1.5 Specific recycling of components

KEY QUESTIONS

1. Are the components of the appliance suitable for a low- or a high-grade recycling route?
2. Is the diversity of separable materials minimal?
3. Are parts of components with different materials separable?

ASSESSMENT: Specialised recycling of components

For the assessment of specialised recycling of components, the criteria are:

- suitability for high- grade recycling (of large plastic components > 25g, printed circuit boards, other components)
- in plastic components > 25g, are no more than two types of incompatible plastics used?
- in plastic components > 25g, are incompatible plastics separable?
- are non-glass parts separable into glass components?
- is the amount of supporting non-metals on printed circuit boards minimal?

Rating of number of materials used in plastic components > 25g:

(- -) > 2 incompatible materials
(#) 2 incompatible materials
(++) No diversity

Rating of large plastic components > 25g with 2 separable plastics:

(- -) Glued, welded, compound component, or inserts
(#) Homogenous, and many stickers
(++) Homogenous

Rating of the percentage weight of supporting non-metals on printed circuit boards:

(- -) Percentage weight of supporting non-metals on printed circuit boards > 15%
(#) Percentage weight of supporting non-metals on printed circuit boards 5- 15%
(++) Printed circuit boards without supporting non-metals

RESEARCH METHOD

The research method for data collection of specialised reprocessing of components is by product examination and material analysis of disassembled components.

Appendix A.

Pilot research project for televisions

Four televisions were chosen for the pilot disassembly test; two were new televisions from the latest test, the other two were old televisions from a collection and disassembly facility. The goal of the pilot disassembly test was to ascertain which criteria were suitable to test on a quantitative basis, and to get data for the rating and weighting of the criteria.

Analysis of disassembly

The analysis of disassembly consisted of:

1. which components are critical for disassembly
2. definition of the most and least optimal design for disassembly.

Components critical for disassembly

The average disassembly times and the estimated standard deviations (n = 4) of the disassembled components are given in Table 1.

The critical components whose disassembly time varies the most between the televisions investigated are, in order of magnitude:

1. back panel
2. deflection unit
3. internal wiring
4. main printed circuit board.

These components are not necessarily the components with the longest average disassembly time, but the components whose disassembly times vary the most. For instance, the average disassembly time of the tube is relatively long, but the disassembly times vary relatively little, and the type and number of connections, and the tools required, are the same for all the televisions examined. (All examined tubes are connected with four screws, for which a socket with ratchet is needed). For this reason, disassembly of the

Table 1: Analysis of disassembly times

Disassembly operation	**Average disassembly time** seconds	**Estimated standard deviation** seconds
Removal of external cables	3	1
Removal of back panel	65	80
Air inlet	17	2
Removal of internal wiring	89.5	29
Removal of main printed circuit boards	48.5	21
Removal of deflection unit	49	59
Removal of degaussing coils	8	7
Removal of tube	73	17
Removal of speakers	27	2
Removal of small printed circuit boards	26	17
Remaining front panel	0	0

tube is not considered critical. From the televisions examined, it was decided that there is, at present, no way in which manufacturers can improve the design for disassembly of the tube, although they should do more work on this.

Television optimally designed for disassembly

The television defined as most optimally designed for disassembly is a notional TV, all of whose components have the shortest disassembly time recorded from the tested televisions. The total disassembly time of such a notional television would be three minutes 48 seconds. Similarly, the television defined as least optimally designed for disassembly is a notional TV consisting of components from the tested television with the longest disassembly time; its total disassembly time would be 11 minutes 43 seconds.

At present, the greatest gain in disassembly time can be yielded by improving the design of its critical components. The television defined as optimally designed for disassembly is a notional television whose critical components have the shortest disassembly time. The connection types of the critical components with the shortest disassembly time are given in Table 2.

A television with the best design for optimal disassembly has two screws to remove the back panel, one screw to remove the deflection unit, 13 cuts needed to remove the internal wiring, and three screws plus one click connection to remove the main printed circuit board.

The connections of the critical components with the longest disassembly time are given in Table 3.

Given the results of this pilot test, the influence of the following items are striking:

- The type of connection has a major influence on disassembly time: if components are glued instead of being connected by screws, as in the deflection unit, this has the effect of increasing the disassembly time considerably

- The diversity of connection types has a direct influence on the disassembly time: the more types of connection in a component, the longer its disassembly time

- The number of one type of connection also affects the disassembly time; for example, the greater the number of screws used in connecting a component, the longer its disassembly time; this is partly accounted for by the time spent finding each screw.

Financial and environmental impact of disassembly and recycling

A sensitivity analysis was carried out in order to be able to prioritise the different assessment aspects. Priority-setting was established with the help of the computer-aided recovery analysis tool Design For Environment (DFE). This software was developed for designers, enabling them to make a financial and environmental end-of-life evaluation of a prototype.

Table 2: Critical components most optimally designed for disassembly

Critical component	**Disassembly time** seconds	**Improvement over average** seconds	**Connections** number, type, cuts needed to disconnect	**Television sample No.**
Back panel	12	53	2 screws	TV4
Deflection unit	2	47	1 screw	TV2
Internal wiring	68	21.5	13 cuts	TV1
Main printed circuit board	30	18.5	3 screws, 1 click	TV2
Total improvement in disassembly time		140		

Table 3: Critical components least optimally designed for disassembly

Critical component	Disassembly time seconds	Deterioration compared with average seconds	Connections number, type, cuts needed to disconnect	Television sample No.
Back panel	181	116	6 screws, 8 cuts, 1 click	TV2
Deflection unit	128	42.5	4 glue, 1 tape, 1 screw	TV4
Internal wiring	132	18.5	6 cuts, 36 electrical connectors	TV4
Main printed circuit board	67	79	1 card guide, 1 material cut	TV1
Total deterioration in disassembly time		256		

To be able to perform the sensitivity analysis, a standard television was defined based on the results of the pilot disassembly test.
The sensitivity analysis consisted of the investigation of the financial and environmental impacts of disassembly and recycling.

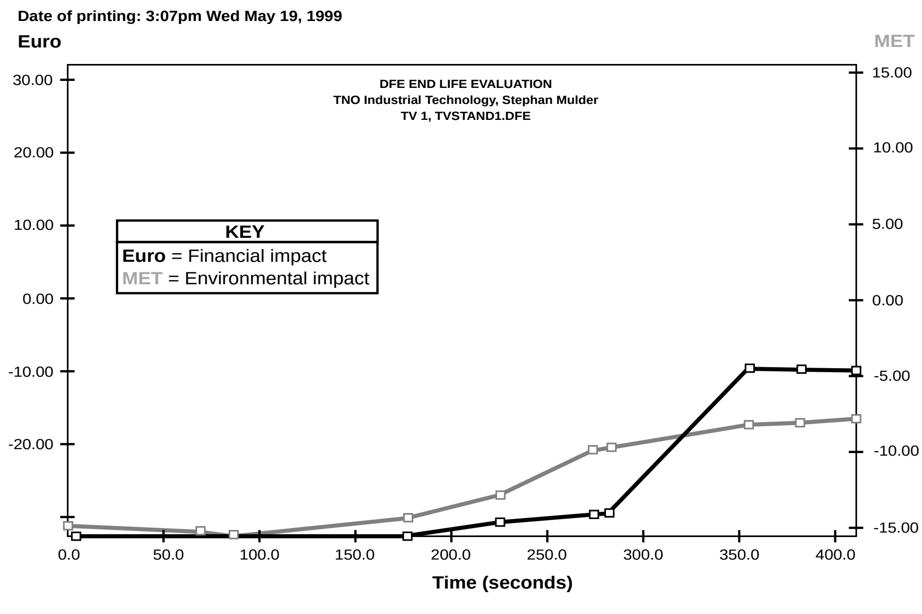
Defining a standard television

The results of the disassembly test were entered into software program DFE. To compare the results of each television in DFE, the disassembly sequence was structured according to current practice of disassembly in recycling centres. A standard television was defined as a television with a diagonal tube size of 60cm. This standard television consists of components generally found in a television. The components of the standard television have the average material weights of the components of the investigated televisions. The disassembly times of each component are the average of the investigated televisions. In defining the standard televisions most and least optimally designed for disassembly, the lowest and highest disassembly times were taken for all components of the standard television.

DFE analysis

The disassembly data and material weights of the standard television were put into DFE, and the resulting end-of-life evaluation graph is presented in Figure 5. In the end-of-life-evaluation graph, the disassembly time on the

Figure 5. End-of-life evaluation of a standard television



horizontal axis is plotted against the financial and the environmental impacts on the vertical axis.

Financial impact

The financial costs / benefits evaluation includes landfill and collection costs, and, with each disassembly step, the disassembly costs and calculated financial returns of re-use, recycling, or incineration.

Financial evaluation begins on the left, without the application of disassembly. The point at which the financial line begins on the left represents the landfill costs of the entire television. After each disassembly step, the financial line will rise with the removal of a valuable component that can be recycled. The financial line shows the strongest rise with disassembly of the tube, even though recycling a tube costs money. This is caused by the size of the landfill costs of a tube, due to its weight, and the toxic substances it contains. The recycling costs of the tube are overshadowed by the landfill costs. The financial line rises because these costs are reduced by removing the tube. The level of the financial line after all components have been disassembled is still negative, and shows what level of removal is necessary for recycling an average television with a 60 cm diagonal tube.

Environmental impact

The environmental impact is expressed by the MET score. The MET score represents the contribution of an appliance to a set of environmental effects such as the greenhouse effect, acidification, smog, eutrophication, exhaustion of resources, ecotoxicity and human toxicity. The MET score is based upon a life-cycle analysis with a distance-to-target approach to the goals set by the Dutch government. The MET score is a one-point score showing how close the appliance is to meeting the desired level. In the MET score, three categories of environmental aspects are taken together in a single measure, namely: material cycle, energy use and toxic emissions (the name MET is derived from the first letter of each category). Material cycle takes into account the extraction and production of raw materials and solid waste, and is related to exhaustion of resources. Energy use is defined as the energy which is used in the phases of the appliance during its life span, and is related to the greenhouse effect, acidification, smog, and eutrophication. Toxic emissions are harmful emissions to water, soil and air, and are related to ozone depletion, human toxicity, and ecotoxicity.

Sensitivity analysis

The sensitivity analysis was carried out in order to be able to prioritise the different assessment categories, which are represented in the general flowchart of the recycling process (Figure 2). The assessment categories are: information to consumers, components containing environmentally harmful substances, disassembly, and material recycling. (For the sake of convenience, the assessment categories ‘material choice and labelling’ and ‘specific recycling’ are summarised under the term ‘material recycling’. Priorities for these assessment aspects were established with the help of DFE. The influence of these assessment categories on disassembly time, recycling percentage, financial impact, and environmental impact forms the sensitivity matrix, which is represented in Table 4.

Information to consumers

The category ‘information to consumers’ has no influence on any of the factors.

Table 4: Sensitivity matrix

Assessment category	**Disassembly time** seconds	**Recycling percentage** kg	**Financial impact** Euro	**Environmental impact** MET
Information to consumers	x	x	x	x
Harmful substances	-	+	+	+
Disassembly process	+	-	+	-
Material recycling	-	+	+	+

Table 5: Impact of disassembly time range for the back panel

Disassembly time, back panel	Total disass-embly time	Recycling percentage	Special waste	Total profits /costs	Cumulative environmental impact
	seconds	%	%	Euros	MET
Short	360	83.2	9	-9.23	-7.872
Average	410	83.2	9	-9.62	-7.872
Long	525	83.2	9	-10.53	-7.872
Difference	165	0	0	1.3	0

Harmful substances

The category ‘harmful substances’ has an influence on the recycling percentage, the financial impact and the environmental impact. Its influence on the recycling percentage is as follows: decreasing the percentage weight of harmful components increases the recycling percentage, because these components can then be recycled. Its influence on the financial impact is strong because the costs of special processing are high. Its influence on the environmental impact is due to the toxic substances; the environmental curve in the DFE graph will be lower with an increasing percentage of harmful substances. For televisions, ‘harmful substances’ has no influence on the factor ‘disassembly time’, because full disassembly applies to that product group. For example, the back panel containing halogenated flame retardants will always be disassembled in order to separate the tube from the remainder. Furthermore, components of televisions containing harmful substances are currently incinerated or recycled.

Disassembly process

The category ‘disassembly process’ has an influence on the disassembly time and thereby the financial impact (through the costs of disassembly). It has no automatic influence on the recycling percentage, but can have an influence on the environmental impact in the case of optimal disassembly. If more components are disassembled, more components can be recycled. For televisions, however, full disassembly applies, so the disassembly process has no influence on the recycling percentage.

In the sensitivity analysis, further attention is given, below, to the impact of the range of disassembly times for the back panel. Attention is also given to the impact of televisions with the best and worst design for optimal disassembly.

Material recycling

The category ‘material recycling’ has an influence on the recycling percentage, the financial impact and the environmental impact. In the sensitivity analysis, further attention is given, below, to the impact of the choice of materials for the degaussing coil. A degaussing coil can be made of aluminium or copper. Attention will also be given to the effect of incineration versus recycling of the back panel. Finally, attention will be given to low- or high-grade recycling of the tube (the ceramic recycling route versus the glass recycling route).

Impact of disassembly time range

The impact of the range of disassembly times for the back panel is represented in Table 5. The financial impact varies by 1.30 Euros.

The impact of the range of disassembly times for televisions with the best and worst design for optimal disassembly is represented in Table 6. The dramatic decrease in disassembly time affects the hourly rate of disassembly. Since differences in the capacity of recycling centres is not covered by DFE, the assumption has been made that the decrease in disassembly costs, relative to the average, affects the hourly rate by 5%.

Impact of recycling range

The impact of the material choice for the degaussing coil is shown in Table 7; Table 8 shows the impact of incineration versus recycling of the back panel; and Table 9 shows the impact of high and low recycling grades of the tube.

Table 6: Impact of disassembly time range of the most and least optimal design

Design for disassembly	Total disassembly time	Recycling percentage	Special waste	Total profits/ costs	Cumulative environmental impact
	seconds	%	%	Euros	MET
Most optimal	228	83.2	9	-8.08	-7.872
Average	410	83.2	9	-9.62	-7.872
Least optimal	703	83.2	9	-12.23	-7.872
Difference	475	0	0	4.15	0

Table 7: Impact of material choice for the degaussing coil

Material choice of degaussing coil	Total disassembly time	Recycling percentage	Special waste	Financial impact	Cumulative environmental impact
	seconds	%	%	Euros	MET
Aluminium	410	83.2	9	-9.62	-7.872
Copper	410	83.3	9	-9.02	-7.875
Difference	0	0.1	0	0.6	0.003

Table 8: Impact of incineration versus recycling of back panel

End-of-life destination of back panel	Total disassembly time	Recycling percentage	Special waste	Total profits/ costs	Cumulative environmental impact
	seconds	%	%	Euro	MET
Incineration	410	83.2	9	-9.62	-7.872
Recycling	410	92.2	0	-6.47	-7,184
Difference	0	9	9	3.15	0.688

Table 9: Impact of high versus low recycling grade of the tube

Recycling grade of tube	Total disassembly time	Recycling percentage	Special waste	Financial impact	Cumulative environmental impact
	seconds	%	%	Euro	MET
Low: ceramic route	410	83.2	9	-9.62	-7.872
High: glass route	410	83.2	9	-13.13	-7.174
Difference	0	0		-3.51	0.698

Table 10: Resulting impact differences of end-of-life scenarios

End-of-life scenario ranges	Recycling percentage %	Special waste %	Financial impact Euros	Cumulative environmental impact MET
Disassembly time, back panel	0	0	1.3	0
Total disassembly time	0	0	4.15	0
Material choice, degaussing coil	0.1	0	0.6	0.003
Incineration or recycling, back panel	9	9	3.15	0.688
Recycling grade of tube	0	0	-3.51	0.698

Table 11: Priority setting for assessment categories

Assessment category	Weighting percentage %
Information to consumers	20
Harmful substances	20
Disassembly process	20
Material recycling	40

If the entire appliance goes to landfills, the material choice of the degaussing coil has an influence on the environmental impact, because copper is more scarce than aluminium. After disassembly of the degaussing coil, the MET points are nearly the same.

If the back panel is incinerated, it is considered special waste, because it contains halogenated flame retardants. If the back panel is recycled, the recycling percentage increases by the percentage weight of the back panel, namely 9%. The difference in financial impact is positive due to the financial returns of recycling HIPS. The environmental impact is reduced because the recycled material can be deployed again as secondary raw material.

The costs for low-grade recycling of the tube are 83 Euros / ton. The costs for high-grade recycling range from 166 to 332 Euros / ton; the average of 250 Euros / ton was taken. The difference in financial impact is negative because the recycling is more expensive. The difference in environmental impact is positive due to the higher quality of the recycled material in the case of high-grade recycling.

Weighting of assessment categories

The resulting impact variations from the range of end-of-life scenarios are represented in Table 10. This shows that the range of total disassembly times has an influence only on financial impact. Incineration versus recycling of the back panel affects the recycling percentage, and both the financial and environmental impacts. On the other hand, the recycling grade of the tube affects the financial impact (negatively), and the environmental impact (positively).

Setting priorities for assessment categories on the basis of these impact differences must be regarded as a proposal. Because the disassembly process has an impact difference on one factor, namely the financial impact, and material recycling has an impact difference on

three factors, of which one will be diminished with high-grade recycling of the tube, the proposal is that the priorities of these two aspects are 1:2 relative to each other. If a priority of 20% is chosen for the assessment category ‘information to consumers’, and the choice is made to put ‘disassembly’ and ‘material recycling’ at 60%, these last two aspects have priorities of 20% and 40% respectively.

Appendix B.

Guidelines for recyclability assessment of televisions

The assessment of recyclability of televisions is based on the pilot research project, and will be presented as follows. For each phase of the recycling process, the guidelines consist of key questions, assessment criteria rating of the applicable research methods.

The product-specific guidelines for televisions are set out in this study. The rating and weighting of the criteria are proposals from Consumentenbond in co-operation with TNO Institute of Industrial Technology of the Netherlands.

Key questions, criteria and research methods

Discarding the appliance

KEY QUESTION

Does the user manual give information on how and where to dispose of the old appliance so it can be collected for recycling?

ASSESSMENT: User manual

The assessment of information on recycling available to consumers in the user manual consists of the following criteria:

- information about how and where consumers can dispose of the television set
- recycling guarantee: mention of whether a recycling guarantee is given when a new system is bought
- information about the different electrical and electronic components and materials used in the appliance
- information about avoiding heavy metals like cadmium, and other harmful materials like PVC and CFCs, halogenated flame retardants
- information about location of components with environmentally harmful substances (polychlorobiphenyl in capacitor of printed circuit board, rechargeable batteries, back panel with halogenated flame retardants).

Evaluation of information on recycling in the user manual:
(- -) no information to consumers in the manual on recycling of the TV
(-) general information about disposal of the television set
(#) information about disposal addresses, disposal of batteries, type of waste
(+) recycling guarantee, and information about location of environmentally harmful components
(++) information about the different electronic components and materials.

RESEARCH METHOD

The research method for data collection of information to consumers is by product inventory.

Components containing environmentally harmful substances

KEY QUESTIONS

1. Are components with environmentally harmful substances found in the appliance?
2. Are components with environmentally harmful substances identifiable and labelled?

3. Are components with environmentally harmful substances easy to disassemble?
4. Does the material output still contain envi ronmentally harmful substances after disassembly of components with environ mentally harmful substances has been applied?

ASSESSMENT: Environmentally harmful components

The assessment of components containing environmentally harmful substances is according the European Directive on waste from electrical and electronic equipment. The assessment of components containing environmentally harmful substances is on the following criteria:

- are rechargeable batteries found?
- does the tube contain cadmium?
- do the electronic components contain cadmium and lead?
- do the back panel and the printed circuit board contain halogenated flame retardants?
- the material labelling percentage: % of components with environmentally harmful substances labelled?
- are labels correct?

Rating of cadmium in the tube[27]:
(- -) tube contains Cd in > 50 mg / kg
(#) tube contains no Cd in > 50 mg / kg
(++) tube contains no Cd
Break factor: if not in compliance with national legislation, then evaluation ≤#.

Rating of cadmium and lead in the electronic components (main printed circuit board and internal wiring):
(- -) electronic components contain Cd in > 50 mg / kg, and Pb in > 0.5%
(#) electronic components contain no Cd > 50 mg / kg, and no Pb in > 0.5%
(++) electronic components contain no Cd and Pb
Break factor: if not in compliance with national legislation, then evaluation ≤#.

Rating of halogenated flame retardants in back panel (in % w / w):
(- -) back panel contains both Br and Sb in > 1 w / w %
(#) back panel contains no Br in > 1 w / w %
(++) back panel contains no Br and Sb

Rating of the percentage of labels on components with environmentally harmful substances:
(- -) no labels found
(-) 20-40%
(#) 40-60%
(+) 60-80%
(++) 80-100%.
Rating of the correctness of each label*

(- -) label not correct
(#) label correct, minimal requirements
(++) maximal requirements
* If more than one label is found, this assessment is repeatedly applied on each label.

RESEARCH METHODS

The research method for data collection of found rechargeable batteries is by product inventory.

The research method for data collection of halogenated flame retardants is by determination of specific flame retardants, determination of the percentage weights of bromine (Br) and antimony (Sb), and confirmation by the Beilstein test:

- determination of specific flame retardants in the back panel and main printed circuit board by pyrolysis mass-spectrometry
- determination of percentage weights of antimony (Sb), bromine (Br) in back panel and main printed circuit board with instrumental neutron activation analysis (INAA)
- determination of presence of halogens (CL, Br) in the back panel by the Beilstein test.

The research method for data collection of cadmium in the tube and electronic components is by determination of percentage weights of cadmium (Cd) with instrumental neutron activation analysis (INAA).

The research method for data collection of labelling is by product inventory.

Disassembly into main components

KEY QUESTIONS

1. Is the appliance designed for disassembly?
2. For which components is disassembly difficult?

3. Can the appliance be disassembled with universal tools?

ASSESSMENT: Disassembly

The total disassembly time is, in principle, the most important criterion. Critical components of which the disassembly time mutually show great differences are selected: they are the components of which disassembly can be difficult.

The criteria for disassembly are:

- total disassembly time
- disassembly time of critical components (back panel, internal wiring, deflection unit)
- type of connections
- diversity of connection types
- number of connections of one type (the number of connections is identical to the number of performed tasks)
- number of necessary tools
- special or non-universal tools
- safety of disassembly.

Rating of the total disassembly time:
(- -) total disassembly time of > 10 min
(-) total disassembly time between 8-10 min
(#) total disassembly time between 6-8 min
(+) total disassembly time between 4-6 min
(++) total disassembly time of < 4 min

Rating of the disassembly time of the back panel:
(- -) > 150 sec
(-) 60-150 sec
(#) 20-60 sec
(+) 5-20 sec
(++) < 5 sec

Rating of the disassembly time of the deflection unit:
(- -) > 90 sec
(-) 40-90 sec
(#) 15-40 sec
(+) 5-15 sec
(++) < 5 sec

Rating of the disassembly time of the internal wiring:
(- -) > 130 sec
(-) 100-130 sec
(#) 70-100 sec
(+) 40-70 sec
(++) < 40 sec

Rating of the disassembly time of the printed circuit board:
(- -) > 80 sec
(-) 60-80 sec
(#) 40-60 sec
(+) 20-40 sec
(++) < 20 sec

Rating of type of connections:
(- -) glued, welded
(#) screw, electrical connector, needs cutting to disconnect, card guide, tape
(++) breaking points, click, clamp (light)

Rating of diversity of connection types:
(- -) > 14
(-) 11-13
(#) 8-10
(+) 5-7
(++) 2-4

Rating of numbers of connections of one type (screws of the back panel):
(- -) > 9
(-) 7, 8
(#) 5, 6
(+) 3, 4
(++) 1, 2

Rating of number of necessary tools:
(- -) > 2 required for a disassembly operation
(-) more tools required than amount of disassembly operations
(#) 2 tools; one in each hand required for one disassembly operation
(+) 1 tool required per disassembly operation
(++) 1 tool required for all disassembly operations.

Rating of special or non-universal tools:
(- -) drill, grinding wheel, hacksaw, power sabre saw
(-) gripping and fixing tools
(#) fixed-end wrench, adjustable wrench
(+) torcx screwdriver, socket with ratchet
(++) universal tools are: flat-head screwdriver, cross-head screwdriver.

Rating of safety of disassembly:
(- -) air inlet is not possible directly after disassembly of back panel
(#) air inlet is possible directly after disassembly of back panel, but obstructed
(++) air inlet is possible directly after disassembly of back panel.

RESEARCH METHOD

The research method for data collection on disassembly is by a laboratory disassembly test and product examination. In the lab disassembly test, the appliance is fully disassembled into its main components. The disassembly guidelines for each product group identify these components, and define a sequence for disassembly. It may, however, be necessary to deviate from this sequence. The aim of the disassembly test is record the times of standard disassembly actions and to record compiled data. The collected data will be recorded in a standard disassembly spreadsheet. The preparation, procedure and disassembly spreadsheet are further described in Appendix A.

Collection of components of the same material: material choice and labelling

KEY QUESTIONS

1. What is the potential material reprocessing percentage?
2. What is the percentage weight of components categorised as valuable, waste, chemical waste?
3. Are materials labelled as to their content?

ASSESSMENT: Collection of components

The assessment of material choice and labelling is on the following criteria:

- percentage weight of components with valuable materials
- percentage weight of components categorised as waste
- percentage weight of components with envi ronmentally harmful substances
- material labelling percentage: % of plastic parts > 25g labelled
- are labels correct (according to ISO 11469)?

Rating of percentage weight of components with valuable materials:
(- -) 0%
(-) 0-16%
(#) 16-33%
(+) 33-50%
(++) > 50%

Rating of percentage weight components categorised as waste:
(- -) > 32%
(-) 24-32%
(#) 16-24%
(+) 8-16 %
(++) < 8%

Rating of percentage weight of components with environmentally harmful substances (this is the tube, the reprocessing costs of the tube equal the costs of special waste):
(- -) > 80%
(-) 70-80%
(#) 60-70%
(+) 50-60%
(++) < 50%

Rating of material labels percentage on plastic parts > 25g:
(- -) no labels found
(-) 20-40%
(#) 40-60%
(+) 60-80%
(++) 80-100%

Rating of label on plastic correct (according to ISO 11469)*:
(- -) material abbreviation not correct
(#) abbreviations for materials and harmful substances (halogenated flame retardants) correct
(++) date of manufacture, trade name, company name, component registration number added

* If more than one label is found, this assessment is repeatedly applied on each label.

RESEARCH METHOD

The research method for data collection on choice and labelling of materials is by product examination and analysis of the material in the disassembled components.

Specific recycling of components

KEY QUESTIONS

1. Are the components of the appliance suitable for a low- or a high-grade recycling route?
2. Is the diversity of separable materials minimal?
3. Are parts of components with different materials separable?

ASSESSMENT: Specialised recycling of components

For the assessment of specialised recycling of components, the criteria are:

- suitability for high-grade recycling (of large plastic components > 25g, tube, printed circuit boards)
- in back panel and front panel, are a maximum of two types of incompatible plastics used?
- in back panel and front panel, are incompatible plastics separable?
- are non-glass parts separable from the tube?
- is the amount of supporting non-metals on printed circuit boards minimal?

Rating of diversity of used materials in back panel and front panel:

(- -) > 2 incompatible materials
(#) 2 incompatible materials
(++) no diversity.

Rating of large plastic components > 25g with 2 separable plastics:

(- -) glued, welded, compound component, or inserts
(#) homogenous, and many stickers
(++) homogenous.

Rating of non-glass parts separable from the tube:

(- -) welded shrink belt, plastic screen
(#) dubious if suitable for tube glass recycling
(++) shrink belt not welded, no plastic screen.

Rating of the percentage weight of supporting non metals on printed circuit boards:

(- -) percentage weight of supporting non-metals on printed circuit boards > 15%
(#) percentage weight of supporting non metals on printed circuit boards 5-15%
(++) printed circuit boards without supporting non-metals.

RESEARCH METHOD

The research method for data collection of specialised reprocessing of components is by product examination and analysis of the material in the disassembled components.

Appendix C.

Requirements and procedures of the disassembly test on televisions

Requirements for the preparation of disassembly test

- Experienced ‘disassembler’
- Record-keeper
- Disassembly location, pneumatic tools
- Stopwatch
- Balance (max 100 kg, with a relative accuracy of +/-50 gram); small weights are measured on a balance with an accuracy of +/-1 gram
- Storage facility for samples (many trays)
- The appliance to be disassembled
- Disassembly guideline for the product group (disassembly level, and sequence of disassembly)
- Standard disassembly form.

Disassembly test procedure

1. Select the component to disassemble.

2. Set out the necessary tools.

3. Start with disassembly. At a signal from the record-keeper, the disassembler starts to disassemble the component in uninterrupted actions. The record-keeper measures the time with the stopwatch. The time stops at the moment when the disassembler has laid the component aside. Any released screws and other connectors are collected in a separate assembling tray (after the test all the screws are collected and weighed).

4. For each disassembled component, the record-keeper writes down:

- recorded disassembly time
- type of connections (or connectors)
- number of connections (or connectors) needed to be loosened to be able to disassemble the component (if several connections can be loosened with one action it counts as one connection)
- special remarks (safety during disassembly, for example spring constructions under tension)
- weight of the component
- composition of materials
- labelling
- tools required
- name and code of the component; each component will be deposited in a separate tray.

5. Return to point 1, until the appliance is fully disassembled.

The reproducibility of the test is guaranteed by:

- tests with various reference products in various laboratories
- comparison with data from a reference product measured in practice at an active disassembly facility: they must coincide.

Repairability module

Contents:

Reader's guide

The methodology for developing the checklist and guidelines for repairability consists of three parts:

1. definitions and preconditions
2. case studies
3. checklist and guidelines.

This repairability module is based on a literature review and expertise from within consumer organisations.

The checklists and guidelines are intended to be used by consumer organisations wishing to start projects on repairability. Examples of DIY repair, repair services and helpline-aided diagnosis are discussed, and case studies are used to develop general guidelines for the assessment of repairability. These guidelines are proposals for the assessment of repairability, and summarise the consumer-oriented research options available.

1 Definitions and preconditions

This section gives definitions of repairability and repair, and covers the stages undergone by a household appliance in the repair process. The repair process is set out in a flowchart. Scenarios for DIY repair and repair services are also discussed.

2 Case studies

The case study product groups investigated for repairability were coffee-makers, washing machines and computers.

Coffee-makers are also taken as a case study on DIY repair: once the decision to repair a coffee-maker has been made, most consumers in the Netherlands will do the repair themselves.[1] The coffee-makers case study is based mainly on a product research project by Consumentenbond, which consisted of an examination of the components most vulnerable to breakdown, a product inventory, a product examination, and an environmental assessment performed with a quick life-cycle analysis.

Since most consumers get their washing machines fixed by a repair service, research concentrated on how consumer organisations set up surveys of consumers' repair experiences.[1]

The computers case study focuses on ability to diagnose faults and the manufacturer's technical support via a helpline or the Internet.[2]

3 Checklists and guidelines

This section includes the general checklist and guidelines. The general checklist contains assessment criteria and research methods for each phase in the repair process, for both DIY repair and repair services. The guidelines are developed from the criteria in the checklist, and consist of key questions for consumers, assessment criteria and, where applicable, a suggested rating scheme, as well as research methods for each phase of the repair process.

[1] Consumentenbond, report Levensduurverlenging (life time extension); 1996
[2] Consumers' Union, Consumer Reports, May 1998, Fix it, Your guide to repairs, reliability

1 Definitions and preconditions

1.1 Repairability

In domestic appliances, the components that break down within the expected life span of the appliance should be easy to replace. These critical components can be vulnerable due to abuse, wear or corrosion.

DEFINITION: Repair
'Recovering the functions of a product by means of replacing or fixing its failed components during its use, but before it is discarded.'[3,4]

In general, repairing an appliance involves first a diagnosis to identify the cause of the defect, and then the replacement or repair of the defective component(s).

DEFINITION: Repairability
'The repairability of appliances is determined by the diagnosability of the defect and by the feasibility of replacing or fixing the failed components so that the appliance can be returned to operating function.'[1,4]

The main focus of this section is replacement of failed components.

1.2 The repair process

When an appliance breaks down, the repair process can be split into several stages. The flow chart of the repair process is shown in Figure 1.[5] Firstly, the consumer makes a diagnosis of the fault and checks on the warranty coverage, before making the repair decision. Replacement of the defective component can be by DIY repair or by contracting it out to a professional repair service (the stages involved in these options are discussed below). Satisfaction with the repair is the last phase in the repair process, ie the repair has succeeded and the appliance is functioning as before.

1.2.1 Broken or malfunctioning appliance

When a household appliance malfunctions or breaks down completely, what consumers notice initially are the symptoms.

DEFINITION: Symptom
A symptom is the problem or complaint a consumer has with the malfunctioning appliance. The most serious symptom is complete breakdown.

When a household appliance malfunctions, ie it works only partially, it will show symptoms that are either typical or atypical for that product group.

The starting point for research on repairability of appliances is to ask the following questions:

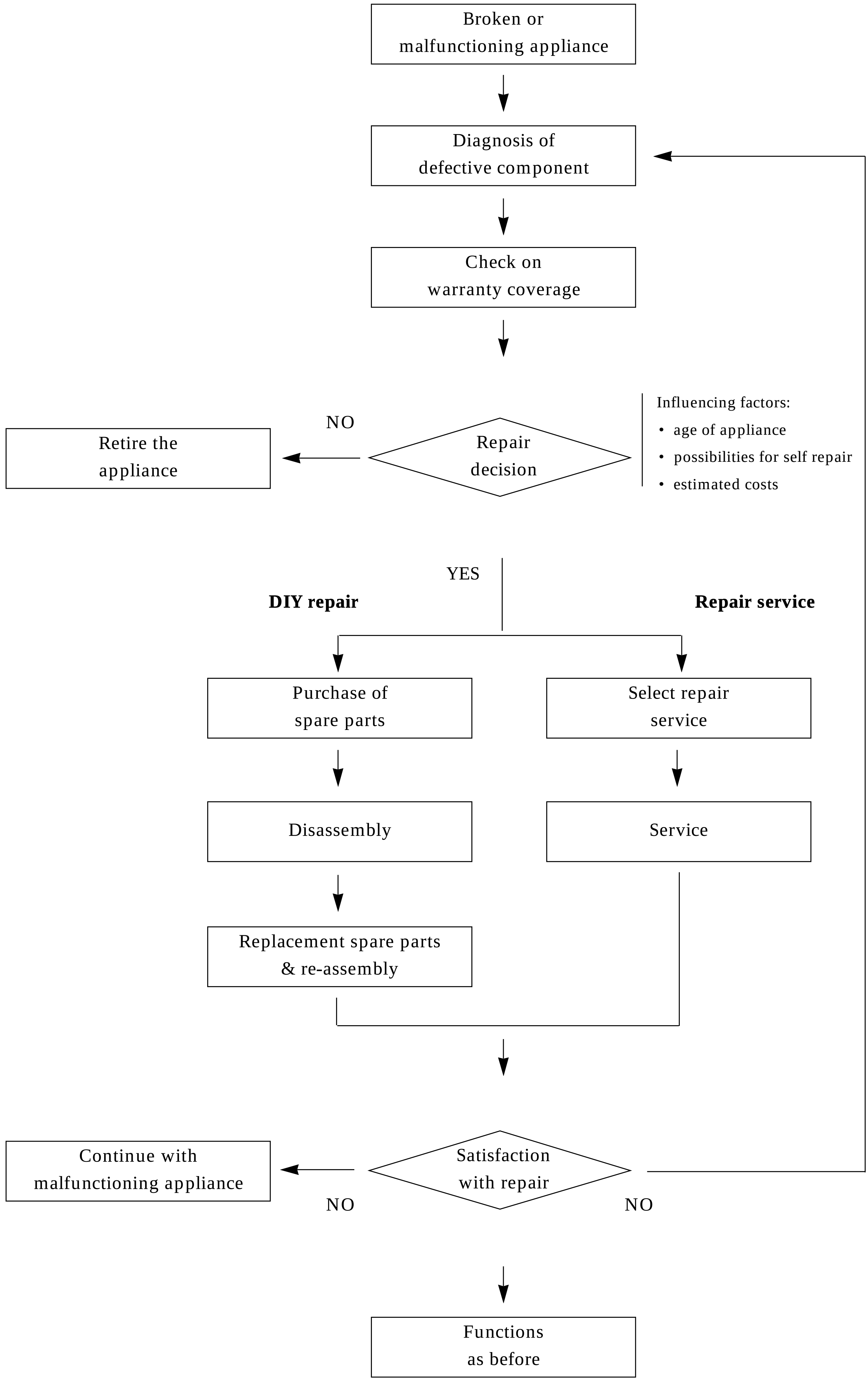
- What symptoms occur most frequently?
- How old was the appliance when the first defect occurred?
- Which components are most vulnerable?

These questions are relevant for consumers wishing to diagnose defects.

---

[3] Penev, Kiril Dimitrov; Design of Disassembly Systems, a systematic approach; 1997
[4] Krikke, Harold; Recovery strategies and reverse logistic network design, Thesis, University of Twente, Enschede, 1998
[5] The flow chart of the repair process was developed as part of this project.

Figure 1. Flowchart of the repair process



1.2.2 Diagnosis of the defect

DEFINITION: Diagnosability
'The capacity to easily identify the source of the problem by detecting which components of the appliance are defective, and by providing the course of action to correct it.'[6]

Manufacturers can help consumers to diagnose defects by giving troubleshooting information in the user manual, or by setting up after-sales services (diagnostic helplines) to deal with problems the average consumer finds difficult to diagnose and repair. Apart from the troubleshooting list, manufacturers should also give information in the user manual on procedures for repair, tools required, and the expected useful life span of vulnerable components and parts.

Information given to consumers in the user manual or through after-sales service can be important to the repair decision, even for an appliance with a high purchase price.

1.2.3 Check on warranty coverage

When an appliance is bought, a guarantee period is normally given. This period varies from country to country. In the Netherlands, the guarantee period is generally one year or more for white goods, and six months for brown goods. In some cases, the standard guarantee can be extended with an extended warranty. The (extended) warranty coverage can be for components and / or labour. Consumers need to ask whether an extended warranty has financial benefits. Is the risk of failure in proportion to the premium paid for the extended guarantee? An EU directive on warranty coverage is in preparation.

During the warranty period, the consumer should have a free replacement or repair, whatever the defect, assuming the appliance was used normally. In Figure 1, the check on warranty coverage may occur at the same time as, or even before, the diagnosis of defective components. Moreover, it is sometimes impossible for the consumer to make a diagnosis, particularly with electronic devices.

1.2.4 Repair decision

When the consumer has diagnosed the defect, s / he should be able to make a balanced decision on whether or not to repair, and to choose between DIY repair and using a repair service. These decisions will differ for each product group, and will depend on several aspects, such as the guarantee or extended warranty coverage, the age of the appliance in relation to its expected life span, the purchase price of the appliance, the possibilities for DIY repair and the estimated costs of repair.

1.2.5 DIY repair

When consumers want to do repairs themselves, the feasibility of replacing failed components is determined by the availability of spare parts, whether the construction is designed for disassembly, and whether the disassembled appliance can be re-assembled without any problems.

1.2.5.1 Purchase of spare parts

Spare parts may not be available immediately. A defective component can be replaced by either a new or a used component, and availability may differ from region to region. Lack of availability of the necessary components will increase the time taken to repair the appliance, and thus the costs. When spare components have to be ordered, the scene is set for the 'waiting for the spare parts' syndrome.

From a consumer's point of view, the availability and price of spare parts ought not to discourage repair. The availability of spare parts is affected by whether parts for different products of the same brand are compatible with each other (interchangeability), and, more to the point, whether spares are compatible with those for the same type of appliance from a different brand (standardisation of components).

1.2.5.2 Disassembly

In order to replace the defective component, the construction of the appliance should be designed for disassembly. In design for

[6] Billatos, Samir B.;Green Technology and Design for the Environment;University of Connecticut; Storrs, C T;Taylor and Francis;1997

disassembly, safety during disassembly must be considered. In addition, the quality and reliability of the product must not be affected after disassembly and re-assembly.

DEFINITION: Disassembly
'To take apart in constituent parts by means of various operations so that the components obtained are not damaged.'[3]

DEFINITION: Design for disassembly
'The aspect of the design methodology which takes into account future disassembly at the end-of-life stage of an appliance. Design for disassembly is influenced by the complexity of the appliance, the detectability and accessibility of the connecting parts, the number of connections, the number of kinds of connecting parts, the number of components, and the tools required.'[7]

In principle, design for disassembly can be measured by disassembly time (an appliance with a complex construction takes more time to disassemble than one with a simple construction).

Disassembly is rated difficult when the accessibility of the connections is troublesome, when high precision is required in positioning the tool, or when much force is needed to loosen the connections.[8]

1.2.5.3 Replacing failed components, re-assembly

DEFINITION: Re-assembly
Re-assembly is, in principle, the reverse of disassembly. Disassembly should be a reversible process. In other words, disassembly should not be destructive; the same tools should be used for re-assembly as for disassembly (connections should not have to be soldered), and the sequence of components to be re-assembled should be the reverse of the sequence of components to be disassembled. It should be possible to carry out the re-assembly with no parts left over at the end; if any are left, the appliance has to be disassembled and re-assembled. It should only be possible to replace each component in one way.

1.2.6 Repair services

When the repair is conducted by a repair service, the following aspects are of interest to consumers: accessibility of the service, time to carry out the repair, costs, and customer service.

1.2.6.1 Selection of repair service

When a consumer wants to contract out the repair, s/he can choose between the retailer where the appliance was bought, a factory or dealer service centre or an independent repair shop; in some cases, s/he is limited to the appliance importer's repair service.

If the consumer has to take the product to a specialised repairer, s/he may have to do without it for a long time while it is being repaired. Consumers may prefer to have the choice of having appliances repaired at home.

1.2.6.2 Service

Repairability is strongly determined by labour costs, which, in turn are determined by complexity and accessibility of construction. If repair is too expensive, practical repairability does not exist.

If mechanical or technical training is needed to carry out the repair, consumers cannot do it themselves. Consumers will be demotivated both by inability to do repairs themselves and by high costs.

When labour is expensive, only high-value items will be repaired. However, a substantial purchase price alone is not enough to promote repairability.

1.2.7 Satisfaction with repair

When the appliance is repaired, it has to function as before. If there are still complaints of malfunctioning, the repair has to be done again, or the consumer may choose to continue to use the appliance with a minor malfunction.

---

[7] Behrendt, Siegfried; Jasch, Christine; Peneda, Maria Constança; Weenen, Hans van; Life cycle design, a manual for small and medium -sized enterprises IZT Institute for Future studies and Technology Assessment, 1997

[8] Kroll, Ehud; Hanft, Thomas; Quantitative evaluation of product disassembly for recycling, Research in Engineering Design, Volume 10 number 1, 1998

2 Case studies

Set out in this section are case studies based on coffee-makers (do-it-yourself repair), washing machines (consumer experiences) and computers (diagnosability).

2.1 Coffee-makers: a case study on DIY repair

Coffee-makers are small domestic appliances, with a purchase price of 20-70 Euros, on which consumers often carry out DIY repair. In a consumer panel survey by Consumentenbond, 57% of the respondents who owned a coffee-maker experienced a defect.[1] In this case study of coffee-makers, attention will be paid to the constituents of coffee-makers, their most vulnerable components, and information to consumers about repairability. This case study is based mainly on research reports by Consumentenbond.

2.1.1 Constituents of coffee-makers

The main components and materials of coffee-makers are shown in Table 1. There is little difference in the construction and variety of coffee-makers.[9] The heating element is part of the base plate, which connects to the housing. The housing and water reservoir are often integrated. The housing is often screwed to the base plate.

2.1.2 Most vulnerable components

The most regular complaints of malfunction in coffee-makers, and the vulnerable components which are most likely to cause them are[1]:

- leaks (34%) Caused by leaking ‘cuffs’, leaking junctions or tubes, hoses. The repair procedure consists of replacing the rubber connection parts, tubes or hoses

- no hot coffee (18%) The heating element has broken down, or is seriously coated in lime scale, the hotplate and / or the bi-metal in the electronics is not working. The repair procedure consists of replacing the entire heating element, whether or not it is integrated with the heating element or the electronics

- short circuit (6%) Poor or non-existent insulation; damaged or inadequate protection of electrical components,

Table 1. Main components of coffee machines[10]

Main components[19]	Weight kg	Main materials[18]
Housing / water reservoir	0.4	ABS
Filter	0.1	ABS
Heating element	0.3	Metal, ceramic
Serving jug	0.3	Glass / ABS
External cable with plug	1.1	PVC and copper

[9] Chemielinco, report 98748; Assessment method of the repairability of coffee machines and vacuum cleaners, 1998
[10] Brezet, Han; Handleiding voor milieugerichte produktontwikkeling, SDU Uitgeverij, 's-Gravenhage, 1994

including the on / off switch. The repair procedure consists of replacing the on / off switch.[9]

2.1.3 Information to consumers

At present, the manuals and warranty conditions of coffee-makers focus on the protection of the customer, and point out that repairs should only be made by specialists. If consumers try to perform DIY repair, all rights for replacement or repairs under warranty become invalid.[9] Manufacturers do not assume that consumers perform DIY repair on coffee-makers. Currently, user manuals of coffee-makers do not contain information about vulnerable components and / or the possibility of replacing them.[9]

2.1.4 DIY repair

About 57% of consumers in the Netherlands who owned a coffee-maker experienced a defect when the machine was, on average, six years old; of these, 30% repaired it. Of the 30%, 73% carried out DIY repair.[1]

2.1.4.1 Availability of spare parts

A random regional telephone survey of spares shops and suppliers of domestic appliances in the Netherlands found that heating elements cost no more than half the purchase price of a new machine.[9] On the other hand, tubes and switches were relatively cheap, although not always in stock (they can be ordered).

2.1.4.2 Disassembly

The criteria which play a role in disassembly and replacement of components are:

- tools required: standard or special
- disassembly time.[9]

Tools required: standard or special

Standard tools are defined as tools available in every average household: normal screwdrivers (flat-head and cross-head), awls, combination and pointed pincers, a set of socket head wrenches, insulating tape, sandpaper, scissors and knife. Special tools are defined as all tools not directly available in most households eg a universal meter, soldering iron, special screwdrivers.

Most coffee-makers contain Torx screw-heads, which can be opened with a normal screwdriver, although this often damages the screws.[11]

Disassembly time

The disassembly time of each removed component is measured, from the first disassembly action until all critical components have been disassembled. In order to obtain comparable data, a standard disassembly sequence has to be recorded. For coffee machines, this was: first the tubes and rubber connection pieces, then the hotplates with attachments, and finally the electronic components (mainly the switch).

Evaluation of Disassembly

A three-point scale (+, #, -) expresses whether the appliance is, as far as disassembly is concerned, seriously limited, limited, or not limited.

(-) Seriously restricted (difficult removable parts, connections difficult to disassemble, the use of specific tools required); accordingly, disassembly is considered impossible for an average household, and damage will occur if it is done
(#) Restricted, but disassembly without damage is possible
(+) No restriction.

Consumentenbond’s research on ten coffee-makers found three that could be disassembled well (+), two with restricted disassembly (#), three that were considered too bad to disassemble (-), and two that were impossible to open.[9]

2.1.4.3 Replacement and re-assembly

Once an appliance has been opened and the vulnerable components are accessible, consumers can perform DIY repair fairly easily.[9]

[11] The pin in the star shaped hole of the Torx screw is damaged by using a flat head screw driver

Re-assembly time

Re-assembly time is measured from assembling the critical component that was replaced first until closing the appliance cover (not including the time taken to test whether the appliance is functioning). Re-assembly of coffee-makers is not always problem-free. In some cases, parts are left over due to the complexity of the construction.

2.1.5 Repair service

Consumer organisations recommend that consumers should always report the defect to the retailer where the appliance was bought, or to the manufacturer.[2] Repair services themselves are reluctant to give repair prices, so these have to be obtained via consumer surveys.[9]

2.2 Washing machines: case study on consumer experiences

On the European market, front-loading washing machines are most common (purchase price is 270-900 Euros). In the United States, by contrast, top-loaders are more common (purchase price is $300-$500). Front-loaders are suitable for building in, while top-loaders are easier to fill. Three out of four Dutch consumers buying a washing machine consider its life span an important aspect.[12] Compared with other product groups (colour televisions, vacuum cleaners, and VCRs), repairability of washing machines has high consumer interest.[1]

In research by Consumentenbond in the Netherlands, 72% of respondents had washing machines that broke down, on average, after nine years; of these, 81% repaired the fault. Front-loading washing machines five years old or less showed a defect in 25% of cases.[12] Consumers' Union in the United States reported a rate of repairs / problems of 23% for washing machines (top-loaders) five years old or less.[2]

This case study is based mainly on research reports by Consumentenbond and Consumers' Union.

2.2.1 Constituents of washing machines

A washing machine is made up of about 150-200 parts. The main components of washing machines are:

- housing / console / fuselage
- barrel / contra weight / drive mechanism
- washing drum / pump
- electric components: timer, electric motor, printed circuit boards, wiring
- hoses
- external cable.[13,14]

2.2.2 Surveys on repairability

For repairability surveys, there are four points to consider:

- target group of respondents: manufacturers or consumers? Consumers' Union surveyed manufacturers in 1998. Consumer questionnaires concern experiences of DIY repair and / or repair services, and are the main subject of this case study

- sample size (per product group). This concerns surveys about consumer experiences of appliance breakdown or frequency-of-repair surveys. If the survey is only about breakdowns, the reliability of a given appliance cannot be inferred. For frequency- of-repair surveys, a larger sample size is required[15]

- product group(s) and / or brands. Product-group-based surveys concern repair of various product groups without any inferences for individual brands. Brand-based surveys usually concern a single product group; for more product groups, larger sample sizes are necessary. The sample size of a brand-based questionnaire depends on the various models within a brand which have 'identity' for consumers. In the case of washing machines, successive models change very little and quality does not differ.[12] The sample size need not be as large as for surveys on cars.

[12] Consumentenbond, Wasautomaten, 1996
[13] Montage und Demontage; Aspecte erfolgreicher Product Konstruction; VDI berichte 999; 1992
[14] Willemze, Martien; Wasautomaten, repareren zonder voorrijkosten, Elektuur, 1988

- period of research. Consumers' Union's latest (1997) annual survey covered experiences from 1992 to 1997, based on 15,160 machines.[15] In the Consumentenbond survey on usage and sensitivity to defects of 1,250 washing machines, respondents were asked only to respond when the washing machine was up to 20 years old.[12]

2.2.3 Most vulnerable components

Consumers' Union asked manufacturers how long top-loading washing machines last (11-20 years), the age at which washing machines are usually replaced (9-20 years), and the components most likely to fail (the pump and the timer).[16]

In the survey on usage and sensitivity to defects of 1,250 front-loading washing machines held in 1995 by the Dutch Consumentenbond, the possible symptoms and defects were coded beforehand. The most commonly-occurring symptoms were: leakage (15%), entire appliance failing to function (14%), and machine failing to perform programme properly (13%).[12]

To infer sensitivity to defects by brand, the frequency of repair and / or brand-related characteristic defects need to be researched: that involves not only the number of faulty appliances but also the number of appliances in use for each period of the faulty appliance's life span and the year of its purchase. For washing machines, defects can be divided into electrical and mechanical defects. The most vulnerable components in the electrical circuit of front-loaders are: timer (27%), pump (motor) (17%), door switch / door security (16%). The most vulnerable mechanical components / mechanical defects are: door clasp / hinge (13%), object to be removed (12%), rubber cuff (12%).

For top-loaders, the most common symptoms are: no water / water everywhere, unit continues / does not work, poor wash performance. The most vulnerable components are the pump, the timer, and the motor / transmission.

2.2.4 Warranties and extended warranties

Warranties are generally for one year; in a few cases, they are for two or three years. In general, the vast majority of faulty household appliances (79%) were not under warranty at the time they broke down, 13% were covered by the regular warranty, and 7% had an extended warranty.[15]According to the Consumentenbond survey, 11% of respondents had taken out an extended warranty at the time of buying their washing machine. Extended warranties are rarely worth having.[12] For major appliances, the costs of service contracts and repairs were on average the same. From a financial perspective, service contracts and extended warranties seems to be of questionable value.[15]

2.2.5 DIY repair

According to the Consumers' Union survey, consumers are more likely to carry out DIY repair on faulty white goods and vacuum cleaners than on major electronic products.[15]

Manufacturers gave Consumers' Union information on how long replacement parts are stocked after a particular washing machine model is discontinued: 7-25 years.

In the Consumentenbond survey, 29% of respondents carried out DIY repair on washing machines. On average, costs of DIY repair are about one-third of those of repair services.[12]

Consumers' Union gives the following expert advice on the care of top-loading washing machines: periodically check the filter for grit build-up where the hose attaches to the hot-water supply pipe.[2]

2.2.6 Repair service

In the Consumentenbond survey, the importer carries out 36% of all repairs, and 35% are done by a local repair service (often via the retailer were the washing machine was bought). In 86% of cases, the repair service arrives within a week. The costs of the repair

[15] Consumers' Union, Annual questionnaire, 1997 survey, published 1998
[16] Consumers' Union, Getting things fixed II, 1998

service were on average 76 Euros. According to the Consumers' Union survey, one in eight respondents complained of high repair costs.[2] In 20% of cases, the same defect occurred again.[12]

2.3 Computers: case study on diagnosability

Computers are expensive household appliances: the purchase price is $1,000-$3,000, or 1,000-2,500 Euros. The life span of computers is usually short. Most people keep their computer an average of five years.[2] They usually replace it out of a desire for new features and advanced technology rather than because it failed. However, according to research in the Netherlands by Consumentenbond, 30% of consumers who owned a computer experienced a defect within three years.[1] According to research by Consumers' Union in the United States, the rate of repair by the time computers are three years old is 19% of units purchased between 1993 and 1996.[17]

This case study is based mainly on research reports by Consumentenbond and Consumers' Union.

2.3.1 Constituents of computers

The basic components of a computer are a keyboard, system unit and a monitor. The two basic system types, or classes of hardware, are:[18]

- the older 8-bit (personal computer / extended class) systems
- 16 / 32 / 64-bit (advanced technology) systems; today, most of these systems would use a 486, Pentium, or P6 processor

The main components of the system unit are:

- motherboard and memory chips (RAM working memory, and SIMMS extra memory chips)
- power supply
- graphics card, I / O card, sound card
- hard drive
- floppy drive
- CD-ROM drive.

2.3.2 Most vulnerable components

Consumers' Union identified common symptoms / complaints by expert opinion, and information on vulnerable components was given by major manufacturers. Common symptoms / complaints and vulnerable components are shown in Table 2.

In research by Consumentenbond, the most frequently occurring complaints are: defective hard drive (14%), inability to restart (13%), and monitor defect (13%).[1] There are two kinds of failures: those when the monitor is still working and those when the screen is blank. If a failure occurs there is no picture and the indicator light is on, the hardware is at fault (the motherboard, graphics card or the power supply). If a failure occurs while the monitor is working, the defect must be in the software or the hard drive.[19]

2.3.3 Information to consumers

Repairs typically begin with a call to the manufacturer's helpline while sitting in front of the computer with any set-up, diagnostic, or recovery disks at hand. According to research by Consumers' Union, each manufacturer has an automated menu of choices, and several levels between the caller and the support representative. Consumers can sometimes wait as long as 20 minutes to speak to someone, and a further 20 minutes to over an hour trying to diagnose the problem. The overall success of the initial contact with the manufacturer, and the repair process in general, depends heavily on the detective skills of the technician at the other end of the phone and of the person who actually comes to the house to repair the fault.[16]

An authorised repairer, if needed, usually turns up within a week; the alternative is to take the computer to a service centre.

Consumentenbond gives the following care tips: back up data (make a copy on diskette of the most important files on the hard disk), avoid viruses with anti-virus programs, and perform regular maintenance (vacuum the ventilation openings of the system unit).[18]

Table 2. Symptoms and vulnerable components of computers[17]

Symptoms/complaints	Vulnerable components	Major/minor
Cannot use a drive or peripheral	Cables	Minor
Erratic cursor movement or no movement at all	Mouse	Minor
Difficulty accessing outside telephone	Modem	Minor
System errors or halts, inability to restart	Hard drive	Major
Cannot read disk	Floppy drive	Minor
Cannot access data on CD	CD-ROM drive	Minor
System crash, inability to restart	Motherboard	Major

2.3.4 DIY repair

In research by Consumentenbond, 20% of respondents whose computers broke down repaired the fault themselves.
Before beginning disassembly, the following precautions should be taken:

- electrostatic discharge protection (to prevent accidental static discharges to the components). Equalise the static charges between the DIY repairer and the components by touching a grounded portion of the chassis, such as the power supply case[18]

- record the set-up and configuration of the system, which can be found in the BIOS software; this is recalled by pressing ‘Del’ or ‘F8’[19]

- record the physical configuration of the system unit, and every action undertaken; if this is a first repair, ask someone experienced for help.

2.3.5 Repair services

In research by Consumentenbond, 80% of respondents whose computer was faulty contracted the repair out to a repair service.

[17] Consumer Reports, May 1996
[18] Mueller, Scott; Upgrading and Repairing PCs, 5th edition, Que Corporation, 1995
[19] Consumentengids, January 1998

3 Guidelines for repairability

The methodology for the assessment of repairability of household appliances was developed using three case study product groups. The guidelines are presented as follows:

- checklist based on a table (Table 1) showing the different stages of the repair process
- description of the key questions, assessment criteria and research methods.

The checklist and guidelines were developed as part of this project.

3.1 Key questions, assessment criteria and research methods

3.1.1 Most frequent symptoms and most vulnerable components

KEY QUESTIONS

1. What are the symptoms that occur most frequently?
2. How old should consumers expect an appliance to be when the first fault appears?
3. What are the most vulnerable components?

3.1.1.1 Most frequent symptoms and complaints

RESEARCH METHOD

Investigating the most frequently occurring symptoms that consumers may encounter with a defective appliance can be done either by questionnaire to manufacturers or by a survey of a consumer experiences. The choice of survey type depends on existing knowledge of symptoms that might occur.

If there is no available information, a questionnaire can be developed to send to manufacturers to get a first impression of possible complaints and causes.

The other method is to draw up an open-question qualitative questionnaire for a consumer panel of at least 100 people, who can enter details of their experiences of repairs and complaints. A minimum of 100 answers per product group must be collected to be able to analyse them for this purpose.

A consumer panel of not less than 1,000 people is necessary for detailed quantitative information. In this case, a list of possible symptoms must be made first; respondents can then mark the symptom they encountered with the defective product.

3.1.1.2 Most vulnerable components

RESEARCH METHOD

To investigate the most vulnerable components of a defective appliance, a questionnaire can be sent to manufacturers, or a questionnaire can be drawn up to investigate consumer experiences. Expert opinion can be sought on the basis of the most regularly occurring symptoms. For example, testing laboratories used by consumer organisations have experience from endurance tests. A literature review may also provide information about the vulnerability of appliances.

The manufacturers' questionnaire and the consumer experiences survey should follow the same rules as set out for most frequently occurring symptoms (see above).

3.1.1.3 Age of faulty or broken down appliance

RESEARCH METHOD

The data are collected via a questionnaire on consumer experiences of repairability. The answers to the questions can be coded beforehand.

In order to find the mean age between purchase and the first defect, it is important to find out when the first defect appeared (as opposed to the second and third). If unknown, the assumption must be made that the answers refer to the most recent defect. The number of times a defect will be experienced and repaired varies from one product group to another. One washing machine can have as many as three defects repaired; with coffee-makers, on the other hand, only the first defect is likely to be repaired, if at all.

3.1.2 Diagnosis

KEY QUESTION

Given the symptoms of the defect, can the available information to consumers help them make an accurate diagnosis of the defect?

3.1.2.1 Consumer information given in the handbook

RESEARCH METHOD

The information is collected via an inventory of the repair section of the user manual.

ASSESSMENT: User manual

Assessment of the information on repairability available to consumers in the user manual consists of the following criteria:

- are the most common symptoms mentioned in the troubleshooting list?
- are the most vulnerable components mentioned in the troubleshooting list?
- is the expected useful life span of vulnerable components mentioned?
- are repair / disassembly procedures for replacing the vulnerable components mentioned?
- are there illustrations of repair / disassembly?
- are the required tools mentioned?
- are service addresses listed?

EVALUATION: information on repairability available to consumers in the user manual

(- -) No information to consumers in the manual on repairability of the appliance
(-) Statement that DIY repair will invalidate the guarantee, and a list of service addresses
(#) Troubleshooting list with most common symptoms
(+) Clear illustrations of DIY repair procedure, vulnerable components
(++) Readable text on DIY repair and disassembly procedures for vulnerable components; expected useful life span of vulnerable components mentioned.

3.1.2.2 After-sales support information to the consumer via helplines

RESEARCH METHOD

The quality of helplines is tested by mystery telephone survey. The questions must represent a relevant symptom of a faulty appliance.

ASSESSMENT: Helplines

The assessment of the information given by helplines to consumers when they experience a broken appliance consists of the following criteria:

- menu of choices, number of levels between the caller and the technical support representative, wait times
- quality of customer service (courteous and knowledgeable)
- toll-free?
- representative asks for zip-code / postcode, name, address and phone number (on warranty card), model of the unit
- procedure to verify the warranty (ease of convincing manufacturers that the appliance was bought less than a year ago,

Table 1. Repairability checklist: phases or repair, criteria, research methods

Stage	Criteria	Research method
Broken or malfunctioning appliance	• Most regularly occurring symptoms & complaints • Age of broken or malfunctioning appliance • Most vulnerable components	Survey of manufacturers and / or consumer experiences, laboratory experience, literature review
Diagnosis of the defect	• Information to the consumer: • troubleshooting list • repair procedures / disassembly • illustrations of repair / disassembly instructions • service addresses • language used, other information • After-sales support (helpline)	Product inventory: manual Mystery telephone survey
Warranty coverage	• covering components and / or labour • Warranty period • Costs in warranty period • Benefit of extended warranty	Product inventory: warranty conditions. Or survey of consumer experiences
Repair decision	• % of respondents repaired appliance • % DIY repair of respondents who repaired • % repair service (importer, manufacturer, or local repair service) of respondents who repaired • Reasons not to repair • Survey of consumers' experiences • Purchase of spare components • Availability of new or second-hand spare parts • Price of new or second-hand spare parts • National, regional availability	Telephone questionnaire, or retailer inventory
Disassembly	• Total disassembly time • Type of connections • Diversity of connection types • Number of connections of one type • Number of necessary tools • Special or non-universal tools • Safety of disassembly	Product examination, or panel simulation
Replacement of defective component & re-assembly	• Overall re-assembly time	Laboratory simulation or panel simulation
Selection of repair service	• Authorised or not? • Repair conditions	Retailer inventory

Stage	Criteria	Research method
Service	• Diagnosis • Conversation when repair taken in • Description of complaint on receipt • Price estimation before work • Prepared list of repair services performed • Costs of repair • Repair time • Customer service • Service guarantee • Exchange appliance provided during repair	Consumer experience survey
Satisfaction with repair	• Appliance damaged • Repair succeeded or not? • Diagnosis was wrong • Second defect shortly after repair	Survey of consumers' experiences

sales receipt not available because it was a gift), and authorisation letter

- length of time on the phone

- number of calls.

EVALUATION: Repairability information to consumers by helplines

The quality of helplines is evaluated on a five-point scale for the following: accessibility by telephone, customer service, and quality of advice.

The proposed weighting factors are:

Assessment criterion	Weighting %	Break factor
Accessibility by telephone	25	
Customer service	25	
Quality of advice	50	if (-)

3.1.2.3 Warranty coverage

KEY QUESTIONS

1. Does the warranty cover components, and / or labour?
2. Does the manufacturer give a 'secret warranty' on the appliance after the official warranty has expired?
3. Does an extended warranty have financial benefit?

RESEARCH METHOD

The information is collected via a product inventory: an inventory of the manual, and a check on the guarantee conditions. Alternatively, a telephone survey of manufacturers can be carried out. Analysis of the financial benefit of an extended warranty is done along with the questions in a survey of consumer experiences.

EVALUATION: Warranty coverage

This is based on the ratio between the expected economic life span and the given guarantee period.

3.1.2.4 Repair decision

KEY QUESTIONS

1. Can consumers make a balanced decision as to whether to repair the appliance or not, and subsequently to do a DIY repair or contract a repair service?
2. What advice do manufacturers give consumers to assist them in the decision of whether or not to repair, so the latter can make a balanced repair decision?

RESEARCH METHOD

The data are collected via a survey of consumer experiences of repairability. The questions concern the reasons not to repair, the percentage of respondents who repaired a broken appliance, and the percentage of DIY repairs versus the percentage who used a repair service.

3.2 DIY repair

3.2.1 Purchase of spare components

KEY QUESTIONS

1. Are spare parts available to consumers?
2. Are the prices of spare parts (new and second-hand) reasonable, relative to the purchase price?
3. Is availability influenced by interchange ability and standardisation?
4. When spare parts have to be ordered, is there the 'waiting for the parts' syndrome?

3.2.1.1 Availability and price of spare components

RESEARCH METHOD

The data can be collected via a telephone survey of retailers who offer spare parts. Another way to obtain relevant data is via a questionnaire on consumers' experiences of repairability. Questions should concern the availability of new or second-hand components, the price, and the of delivery period if spare components have to be ordered. A comparison can be made between the availability of spare parts suitable for only one product and interchangeable and standardised components.

EVALUATION: Availability of spare components

(- -) Not available
(-) Long waiting time and high purchase price
(#) Poor availability
(+) Good availability
(++) Good availability and standardised.

3.2.2 Disassembly

KEY QUESTIONS

1. Is it possible to reach the defective component in order to replace it?
2. How much time do consumers need, on average, to disassemble the appliance in order to reach the defective component?
3. What tools do consumers need for disassembly? Are standard or special tools needed?
4. Is disassembly difficult for consumers?
5. Is it safe to disassemble the appliance?

RESEARCH METHOD

The data can be collected through an inventory and a laboratory disassembly simulation test, with an expert panel of up to three people.

Another way to collect data is a consumer panel test using at least 20 people.

ASSESSMENT: Disassembly

The assessment with a disassembly simulation test is based on overall disassembly time, which automatically covers complexity of construction and difficulty of disassembly. Besides overall disassembly time, it is necessary to record the number and types of connections, required tools, and the difficulty of disassembly.

The assessment of disassembly consists of the following criteria:

- total disassembly time
- type of connections
- number of connection types
- number of connections of one type
- number of necessary tools
- special or non-universal tools
- safety of disassembly.

EVALUATION: Disassembly

(- -) Disassembly not possible, either because it is not possible to open the appliance, or because it would destroy the appliance
(-) Problems with disassembly; disassembly is difficult (obstructed, or requires high precision, or much force); long disassembly time (for coffee-makers more than 15 minutes); special tools needed
(#) Possible problems with disassembly, if problems in chassis and plastic parts, or if there is a glued connection
(+) No problems for disassembly; disassembly time is reasonably good; arrangement of chassis and plastic parts cause no problem; the connections are screw or click type
(++) Disassembly with few actions, short disassembly time (for coffee-makers less than four minutes); 'sandwich' construction (for disassembly, the components are removed in one uniform direction).

3.2.3 Replacement of defective part, re-assembly

KEY QUESTIONS

1. Can consumers re-assemble the appliance without difficulties?
2. Are disassembly and re-assembly non-destructive?
3. Is the re-assembly process the reverse of disassembly?

RESEARCH METHOD

The data can be collected through inventory and disassembly simulation test in a laboratory, with an expert panel of up to three people. Another way to collect data is a consumer panel test using more than 20 people.

ASSESSMENT: Re-assembly

The assessment of re-assembly is dominated by the overall re-assembly time (as with disassembly). A second criterion is the reversibility of re-assembly.

The assessment of re-assembly is on the following criteria:

- overall re-assembly time
- is re-assembly process the reverse of disassembly?
- is disassembly a reversible process? Are the same tools needed for re-assembly as for disassembly (is soldering of connections needed)?
- is the sequence of re-assembly the reverse of disassembly (possibility of parts left over)
- replacement of spare parts should be carried out in one possible way only.

EVALUATION: Re-assembly

(- -) Disassembly is destructive, or re-assembly did not succeed
(-) Spare part is replaceable with special tools
(#) Reasonable re-assembly, actions the same as with disassembly
(+) Easy re-assembly, spare part replaceable in only one way
(++) Re-assembly is the reverse of disassembly, short re-assembly time (for coffee-makers less than four minutes)

3.3 DIY repair: weighting the criteria for repairability

The proposed weighting factors are:

Assessment criterion	Weighting %	Break factor
Information to consumers	20	
Availability of spare parts	20	if (- -)
Disassembly	40	if (- -)
Re-assembly	20	if (- -)

3.4 Repair services

3.4.1 Selection of repair service

KEY QUESTIONS

1. Can consumers make a balanced decision about which (type of) repair service to select?
2. Do manufacturers give information and guidelines to consumers on what to do and where to go?

RESEARCH METHOD

Information is collected by an inventory of the manual. Consumer organisations can advise consumers which repair service to select by assessing them through a mystery shopping survey.

3.4.2 Service

KEY QUESTIONS

1. What experiences have consumers had with the different types of repair service?
2. Does the repair service give a receipt beforehand, containing diagnosis, maximum price and date of delivery?
3. What are the costs of repair?
4. What is the repair time?
5. What is the quality of the customer service given by the repair service?

RESEARCH METHOD

Data on consumers' experiences of repair services are collected through a consumer survey.

Alternatively, repair services may be assessed by seeing how well they repair defective appliances. A mystery shopper delivers an appliance with a previously well-defined defect to a repair service. Acquiring appliances with the same defect and the same age will be very difficult. If possible, new appliances can be given an artificial defect.

ASSESSMENT: Repair services

The assessment of the repair service is on the diagnosis made by the repair service before the repair is carried out, the quality of the repair service, and the customer service:

- Diagnosis by repair service

- does the repair service ask relevant questions about symptoms, complaints, and warranty?

- does the repair service give a receipt to the consumer before starting work?

- does the receipt include the complaint and the diagnosis of the broken appliance?

- does the receipt include an estimate of the repair cost and a delivery date?

- is the diagnosis given by the repair service technician correct?

- Quality of repair service

- service

- the costs of repair

- the repair time
- Customer service

- can consumers have an alternative appliance while theirs is being repaired?

- does the repair service give a repair guarantee?

3.4.3 Satisfaction with repair

KEY QUESTIONS

1. How satisfied is the customer with the repair service?
2. Was the repair successful or not?

RESEARCH METHOD

Collection of data on satisfaction with repair experiences is done along with the questions in the consumer experiences survey.

Upgradability module

Contents:

Reader’s guide

The methodology for developing the checklists and guidelines for upgradability consists of three parts:

1. definitions and preconditions
2. case studies
3. checklist and guidelines.

The checklist and guidelines are intended to be used by consumer organisations wishing to start a project on upgradability. These guidelines are proposals on how to assess upgradability, and summarise the available methodological options for consumer-oriented research.

This upgradability module is based on a literature review, and on research reports by consumer organisations.

1 Definitions and preconditions

This section gives definitions of upgradability and upgrading, and discusses the stages that household appliances undergo in the upgrading process. The upgrading process is set out in a flowchart. The scenarios of DIY upgrading and upgrading services are discussed. Some definitions are the same as those in the Repairability module.

2 Case studies

For upgradability, one case study product group is investigated, namely computers. Upgrading applies mainly to high-technology appliances such as computers, and to a lesser degree to electrical household appliances such as washing machines. The computers case study was chosen as a model for the DIY upgrading scenario, and is based mainly upon a research report by Consumentenbond.

3 Checklists and guidelines

This section gives general checklists and guidelines. For the scenario of DIY upgrading, a general checklist was developed. This contains, for each stage in the upgrading process, the corresponding assessment criteria and research methods required. The guidelines consist of the key questions, assessment criteria, and research methods for each phase of the upgrading process.

1 Definitions and preconditions

1.1 Upgradability

Consumers can extend the life span of an appliance by upgrading components in it. Upgrading applies especially to high-technology appliances with a rapid rate of innovation, such as computers.

DEFINITION: Upgrading
Extending the functions of a product by means of substituting improved components for the existing components, or by adding new components to the appliance during its use. Upgrading improves on the appliance's original performance or adds new features to it. For example, the memory capacity of a TV can be expanded, giving it increased functionality.[1]

DEFINITION: Upgradability
The upgradability of appliances is determined by consumer demand for improvements, and by the feasibility of substituting or adding improved components that allow the appliance to function at a higher level. A design for DIY upgrading would be as modular as possible, allowing the appliance to be customised.

Where appliances are leased, manufacturers have an incentive to design their products for upgrading. A good example is the upgrading of photocopiers. Similarly, the transition from ownership towards services in consumer purchases could be a further impetus towards enhanced sustainability.

1.2 The upgrading process

When consumers want to upgrade their appliance, several stages of the upgrading process can be identified. These stages are shown in Figure 1.[2] The first step is to check whether the old appliance is suitable for upgrading. The decision is then made whether or not to upgrade. Consumers can upgrade their household appliances in two ways: by DIY upgrading or by using an upgrading service.

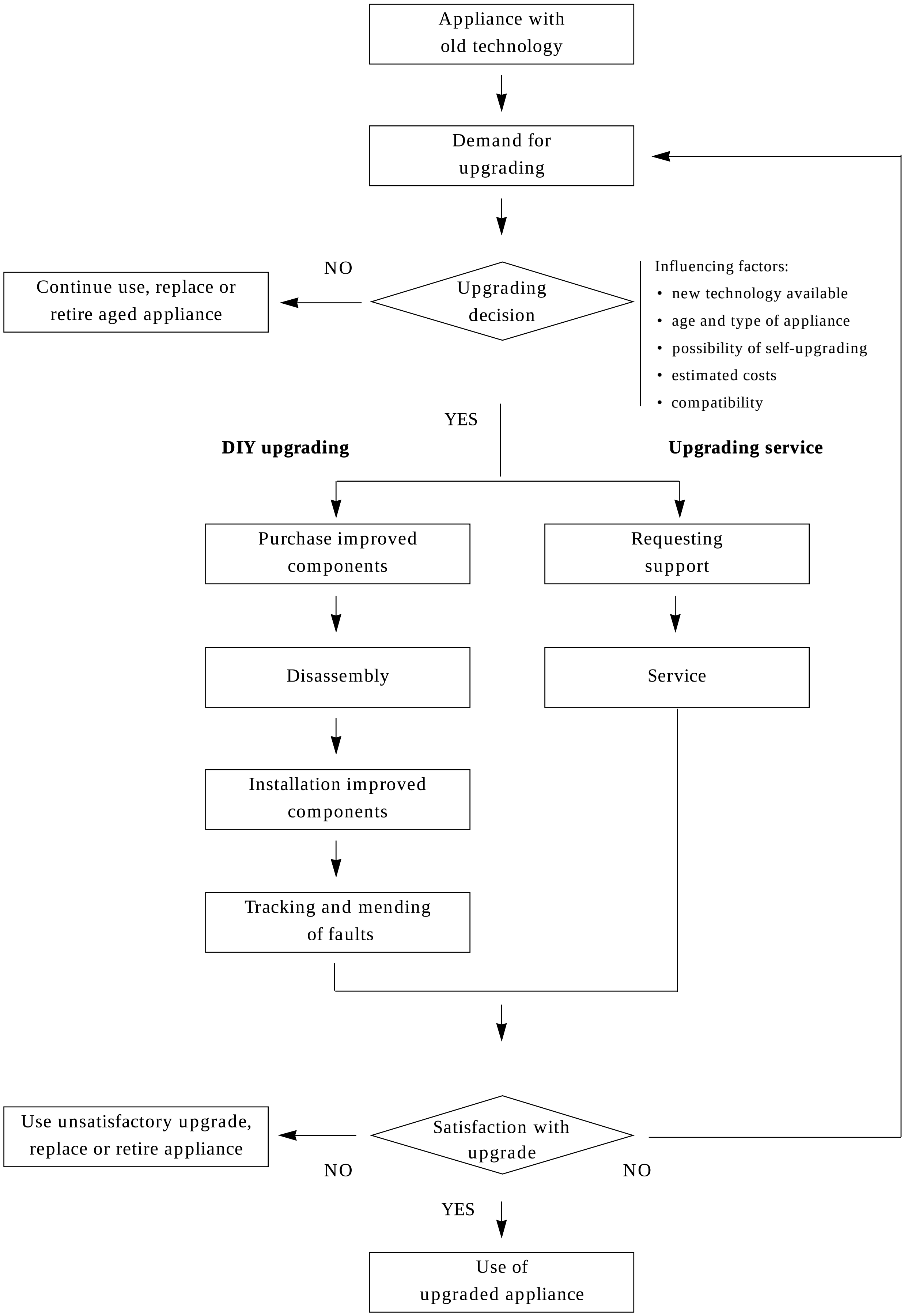
1.2.1 Appliance with old technology

Consumers who own an appliance that uses outdated technology compared with products currently on the market may want to upgrade it: they are stimulated to do so by advances in technology. Most old appliances are not suitable for upgrading: if too many components have to be installed, upgrading is not advisable. Consumers have to establish which functions of the old appliance lack the latest technological developments, and what they want to achieve.

DEFINITION: Functional gap
The functional gap is the complaint consumers have about the operational function of the outdated appliance, relative to available advanced technology.[3] A functional gap is the difference between the current operation of the function and the operational function consumers want to acquire, given the technological state of the art.

[1] Krikke, Harold; Recovery strategies and reverse logistic network design, Thesis, University of Twente, Enschede, 1998
[2] The flowchart of the upgrading process was developed as part of this project
[3] The term 'functional gap' was developed as part of this project

Figure 1. Flowchart of the upgrading process



The starting point for research on upgradability is to find answers to the following questions:

- Which functions of the old appliance do not work to the standards of available advanced technology?
- Which types of appliance are unsuitable, and which are borderline cases for upgrading?
- What complaints do consumers have about the operating functions of their old appliances, relative to new technology?
- Which functional gap do consumers want to close (what do consumers want to attain)?
- Which components most commonly need to be upgraded?

1.2.2 Demand for upgrading

Once the consumer knows what the functional gap is, s / he has to find out which components can be improved or added. Closing the functional gap depends on all the components together and their compatibility, rather than on one hyper-technologically improved component.

Manufacturers can ease the decision-making process on whether to upgrade by giving information through their after-sales service about new technological developments, available improved or additional components, possible upgrading strategies (upgrading options listed in order of convenience and costs), procedures for upgrading, required equipment, and service addresses. Consumer organisations can ease consumer decision-making by giving information on the necessity and best options for closing the functional gap.

1.2.3 Upgrading decision

When the consumer has established how to close the functional gap, s / he should be able to make a balanced decision on whether or not to upgrade, and to choose between DIY upgrading and using an upgrading service. These decisions depend on several issues, such as the age the type of the appliance, the possibility of DIY upgrading, the estimated costs relative to the upgrade benefit, and whether the improved components are backwards compatible (see definition, below).

1.2.4 Purchase of improved components

Availability of the necessary improved components may differ according to region. Lack of availability will increase the time taken to replace or install the new components, and thus the costs. When the improved components have to be ordered, the scene is set for the ‘waiting for the part’ syndrome (long delay before the new component is delivered).

From a consumer’s point of view, the availability and price of improved components should not discourage upgrading. Consumers must be well informed to purchase the right improved components, which are compatible with the configuration of their old appliance. Consumers should be able to acquire this information by reading the manual, by asking the retailer’s advice.

The improved components should be backwards compatible with the old appliance for a given period.[4]

DEFINITION: Backwards compatibility
The possibility of connecting improved components to old appliances containing outdated connection techniques.

1.2.5 Disassembly

In order to replace or install the improved component the construction of the appliance should be designed for disassembly. The ideal situation is minimal disassembly with only a few actions.

In design for disassembly safety during disassembly must be considered. And the quality and reliability of the product must not be affected after disassembly, installing and re-assembly.

[4] EU Ecolabel for personal computers – Draft Criteria (version 1.2), 1998

DEFINITION: Disassembly process
'The process of separating into constituent parts by means of various operations so that the obtained components are not damaged.'[5]

DEFINITION: Design for disassembly
'The aspect of the design methodology which takes into account future disassembly at the end-of- life stage of an appliance.'[6]

Design for disassembly is influenced by the complexity of the appliance, detectability of the connecting parts, accessibility of connecting parts, number of connections, variety of connecting parts, number of components, and tool requirements.[6] In principle, design for disassembly can be measured by the disassembly time (an appliance with a complex construction takes more time to disassemble than one with a simple construction).

Disassembly is rated difficult when the accessibility of the connections is troublesome, when high precision is required in positioning the tool, or when much force is needed to loosen the connections.[7]

1.2.6 Installation of improved components, re-assembly

After disassembly, improved components are substituted or added in order to upgrade the appliance. Consumers need information on how to install the right components, which are compatible with the configuration of the appliance.

Re-assembly should be the reverse of disassembly.[8] Disassembly should be a reversible process. In other words, disassembly should not be destructive; the same tools should be used for re-assembly as for disassembly (connections should not have to be soldered), and the sequence of components to be re-assembled should be the reverse of the sequence of components to be disassembled. It should be possible to carry out the re-assembly with no parts left over at the end; if any are left, the appliance has to be disassembled and re-assembled. It should only be possible to replace each component in one way.

1.2.7 Tracing and mending faults

After replacing or installing the improved components, the appliance may not function optimally. This is especially true in the case of computers, where tracing and mending of faults may be troublesome; however, software programs are available to simplify installation.

1.2.8 Requesting support

For high-technology appliances, consumers will initially request support from the supplier (the retailer where the appliance was bought). But the importer, or independent retailers, can also be asked. Product support is important to consumer satisfaction in both high- and low-technology sectors, but it is particularly important for high-technology products.[9]

1.2.9 Service

An upgrading service can be performed by an authorised technician at home or at the retailer's premises. The upgrading service is strongly determined by labour costs. If the upgrade is too expensive, upgrading is not a practical proposition. Labour costs depend on the time required to upgrade, which is influenced by the complexity and accessibility of the construction, and on the staff required. If special skills are necessary to do the upgrading, consumers cannot do it themselves.

1.2.10 Satisfaction with the upgrade

The upgraded appliance should function at the higher level claimed for the new component. If there are still problems with the operating functions, other components may have to be upgraded as well, or the consumer may choose to continue to use the appliance without one of the functions being upgraded – or even to replace the whole appliance. Even if the upgrade produced an obvious improvement, it may not have been worth the cost.

---

[5] This definition is also given in the Repairability and Recyclability modules
[6] Behrendt, Siegfried; Jasch, Christine; Peneda, Maria Constança; Weenen, Hans van; Life cycle design, a manual for small and medium-sized enterprises IZT Institute for Future studies and Technology Assessment, 1997
[7] Kroll, Ehud; Hanft, Thomas; Quantitative evaluation of product disassembly for recycling, Research in Engineering Design, Volume 10 number 1, 1998
[8] This appears as the definition of Re-assembly in the Repairability module
[9] Goffin, The journal of product innovation management, January 1998

2 Case study

2.1 Computers: a case study on DIY upgrading

Computers are expensive household appliances (the purchase price is $1,000-$3,000, or 1,000-2,500 Euros) which go out of date quickly. Most people keep their computer an average of four years[10] before deciding to replace or upgrade in order to keep up with the latest technological developments. Upgrading a computer enables consumers to keep fairly up to date for a reasonable price. This case study is based on a review of the literature (in particular, reports by Consumentenbond, and uses many technical terms; it is taken for granted that the reader is familiar with computer terminology.

2.1.1 Constituents of computers

The basic components of a computer are a keyboard, system unit, and a monitor. The two basic system types, or classes of hardware, are:[11]

- the older 8-bit (personal computer/extended class) systems
- 16/32/64-bit (advanced technology) systems; today most of these systems would use a 486, Pentium, or P6 processor.

The main components of the system unit are:

- motherboard and memory chips (RAM working memory, and SIMMS extra memory chips)
- power supply
- graphics card, I/O card, sound card
- hard drive
- floppy drive
- CD-ROM or DVD drive

Computers with a 386 processor are not suitable for upgrading because too many components have to be upgraded. Computers with a 486 processor of the first generation, with a low timer speed of 25-33 MHz, are borderline cases. These appliances can be upgraded, but the low picture speed can't be changed because modern, fast video cards are not backwards compatible: these modern video cards are compatible with PCI slots of the motherboard, not with the old ISA and VESA LB slots.[12]

2.1.2 Closing the functional gap: improved components

The main functions of computers that consumers want to improve are the working speed, the working memory, storage capacity, and new features such as viewing photos and playing CDs or video clips (see Table 1). To use Windows 95, consumers must expand the working memory, the storage capacity and the speed of the computer.[13]

2.1.3 Purchase, disassembly and installation of improved components

2.1.3.1 Disassembly preparations

Before beginning disassembly, the following precautions should be taken:

- electrostatic discharge protection (to prevent accidental static discharges to the components): equalise the static charges

[10] Fix it, Your guide to repairs, reliability, Consumer Reports 12-19, May 1998
[11] Mueller, Scott; Upgrading and Repairing PCs, 5th edition, Que Corporation, 1995
[12] Upgraden minder simple als het lijkt, Consumentengids, January 1998
[13] This case study is based on 1997 data; nowadays consumers may want to use Windows 98

Table 1. Functional gaps and improved components to close them

Functional gap	Upgraded component required
Working memory (RAM)	SIMMS and EDO or fast page chips
Working speed	Processor or overdrive processor
Storage capacity	Hard disk
Picture speed	Graphics card
High resolution images, photos	Graphics card
Play video CDs, clips	MPEG card or graphics card

between the DIY repairer and the components by touching a grounded portion of the chassis, such as the power supply case[12]

- recording the set-up and configuration of the system, which can be found in the BIOS software, recalled by pressing 'Del' or 'F8'[13]
- recording the physical configuration of the system unit, and recording every action undertaken; if it is your first time, get help from someone who has often carried out repairs.

2.1.3.2 Expanding working memory

Adding memory to a system is one of the most useful and least expensive upgrades consumers can perform.[12] Additional memory chips (SIMMS) need to be installed, but consumers need to buy SIMMS with the right amount of pins and the right speed (to conform with the speed of the computer). Consumers then need to know if they require EDO chips (new) or fast page chips (old). The best advice consumer organisations can give is to take the old SIMM to the retailer to find out exactly what to buy.

2.1.3.3 Installation of cards

A system unit can contain various types of cards, installed in slots in the motherboard. As mentioned, there are two types of slots, the PCI slots and ISA slots. Cards compatible with PCI slots are easy to insert because no problematic additional manual installation is required, as is the case with ISA slots. With Windows 95, the software automatically selects a suitable driver (steering program); otherwise, consumers have to install a suitable driver via the 'configuration screen'. The latest versions of drivers can be found on the Internet.

If the graphics card is too slow it needs to be replaced. Replacing the graphics card also depends on the type of monitor used: the maximum resolution the card can deliver depends on what the monitor can show. If the graphics card is integrated into the motherboard, adding one in a vacant slot is more problematic, involving switching the old one off by moving jumpers (contact bridges).

2.1.3.4 Installing new processor

It should be possible to replace the processor without replacing the entire motherboard.[4] If the processor is soldered on to the motherboard (as with the 486 SX), replacement of the processor is not possible. In some cases, an expensive overdrive processor can be installed which switches off the old processor. The documentation of the computer should contain information as to which processors and overdrives are compatible with the motherboard.

Sometimes the processor is not directly accessible: other components must be removed to reach it. A couple of jumpers (contact bridges) may also need to be moved.

2.1.3.5 Increasing hard disk memory

A computer with a 1GB hard disk not a luxury.[14] Windows 95 requires 100MB just for itself. If the hard disk already has a large memory capacity, and there is enough space in the computer, an additional hard disk can be installed. Otherwise, it is best to replace an

[14] This case study is based on 1977 data; nowadays hard disks of 13-20 GB are available

old, small-capacity hard disk (less than 100MB). Currently, it is preferable to replace a hard disk with one of the same brand. Replacing a hard disk is easier than adding one.[15]

When purchasing a hard disk, it is important to consider what type of interface (the link between the hard disk and the rest of the computer, also often called the controller) the computer has; the documentation should contain information about it.

[15] Consumentengids, January 1998, page 16

3 Guidelines for upgradability

The checklist and guidelines for the assessment of upgradability of household appliances were developed in this study, using the computers case study. The guidelines for upgradability are presented as follows:

- the checklist based on a table (Table 1) containing the different phases of the upgrade process
- description of the key questions, assessment criteria and research methods

The checklist and the guidelines were developed as part of this study. Upgrading is an extension of repairability, so there is a large overlap between the guidelines in this module and those in the Repairability module; footnotes indicate where this applies.

3.1 Key questions, assessment criteria and research methods

3.1.1 Appliance with old technology and most common functional gaps

KEY QUESTIONS

1. Which functions of the old appliance do not working to the standards of available advanced technology?
2. Which types of appliance are not suitable for upgrading, and which are borderline cases?
3. What are the most common functional gaps (what do most consumers want to attain)?
4. Which components are most commonly in need of upgrading?

3.1.1.1 Appliance with outdated technology

RESEARCH METHOD

Information on which functions of old appliances do not work to the standards of available advanced technology can be collected by expert opinion (a panel of at least three), or by sending a questionnaire to manufacturers or suppliers (at least ten). The same applies to information about which types of appliances are not suitable for upgrading, and for borderline cases.

3.1.1.2 Most common functional gaps

RESEARCH METHOD

Information about the most frequent functional gaps, and which components are most commonly improved, can be collected by expert opinion (a panel of at least three), by sending a questionnaire to manufacturers or suppliers (at least ten), or by sending a questionnaire to consumers (at least 1,000).

3.1.2 Demand for improvement

KEY QUESTION

Given the functional gaps, can the information available to consumers help them make an accurate assessment of how to close them?

3.1.2.1 Information to consumers in the manual

RESEARCH METHOD

Information is collected via an inventory of information on upgrading in the manual.

ASSESSMENT: User manual

Assessment of the information on upgradability available to consumers in the user manual consists of the following criteria:

- are the types of appliances that are not suitable, and borderline cases, mentioned?
- are the most common functional gaps mentioned?
- are the most often improved components and an upgrading strategy list mentioned?
- are upgrade / disassembly and installation procedures mentioned?
- are there illustrations of upgrade / disassembly instructions?
- are the required tools / equipment mentioned?
- are service addresses listed?

Evaluation of information to consumers on repairability in the user manual:

(- -) No information to consumers in the manual on upgrading the appliance

(-) Statement that: 'DIY upgrading invalidates guarantee', and a list of service addresses

(#) List with most common functional gaps

(+) Clear illustrations of DIY upgrade procedure and improved components

(++) Readable text on DIY upgrading and disassembly procedures for improved components; upgrading strategies mentioned

3.1.2.2 Product support: consumer information from suppliers/retailers

RESEARCH METHOD

The quality of information and support provided by suppliers and retailers is tested by a mystery shopping survey. The questions must relate to an appropriate functional gap of an outdated appliance.

ASSESSMENT: Product support

The assessment of product support from suppliers and retailers to consumers wishing to upgrade consists of the following criteria:

- waiting times to speak to the technical support representative
- quality of customer service (courteous and knowledgeable)
- length of consultation time
- free consultation
- number of consultations.

Evaluation of product support on upgradability by suppliers and retailers:
The quality of product support is evaluated on a 5-point scale for accessibility by telephone, service treatment, and quality of the advice.

3.1.3 Upgrading decision

KEY QUESTIONS

1. Can consumers make a balanced decision about whether to upgrade the appliance or not, and subsequently to do DIY upgrading or to request upgrading service?
2. What advice do manufacturers give consumers to help them decide whether or not to upgrade, so they can make a balanced upgrading decision?

RESEARCH METHOD

The data are collected via a survey on consumer experiences of upgradability. The questions concern the reasons not to upgrade, the percentage of respondents who upgraded an old appliance, and the percentage of DIY upgrading versus using an upgrading service.

3.2 DIY upgrading

3.2.1 Purchase of improved components

KEY QUESTIONS

1. Are improved components available to consumers?
2. Are the prices of improved components reasonable relative to the purchase price?
3. Is the availability influenced by inter changeability and standardisation?
4. When improved components have to be ord-ered, is there the 'awaiting parts syndrome'?
5. Are improved components backwards compatible?

Table 1. Checklist on upgradability: phases of repair, criteria, and research method

Phase of upgrading	Criteria	Research method
Appliance with outdated technology	• Most common complaints of functional gaps • Appliance suitable for upgrading • Components most commonly in need of improvement	Survey of manufacturers, and / or survey of consumers' experiences; and / or expert opinion
Demand for improvement	• Information to the consumer • improved components and upgrading strategy list • upgrading procedures / disassembly and installation • illustrations of upgrading / disassembly instructions • service addresses • language, other information • Retailer / supplier support	Product inventory: manual Mystery shopping survey
Upgrading decision	• % of respondents who upgraded old appliance • % DIY upgrade of respondents who upgraded • % upgrading service (importer, manufacturer or local retailer) of respondents who repaired • Reasons not to upgrade, but replace	Survey of consumers' experiences
Purchase of improved components	• Availability of improved components • Price of improved components • National, regional availability	Telephone survey, or retailer inventory
Disassembly	• Total disassembly time • Type of connections • Diversity of connection types • Number of connections of one type • Number of necessary tools • Special or non-universal tools • Safety of disassembly	Product examination, or panel simulation
Installing improved component, re-assembly	• Total re-assembly time • Installation time	Laboratory simulation, or panel simulation
Tracing and mending faults	• Total time required for tracing and mending faults	Laboratory simulation, or panel simulation
Selection of upgrading service	• Authorised or not? • Upgrade conditions	Retailer inventory

Phase of upgrading	Criteria	Research method
Upgrading service	• Determination of consumer demand for upgrading • intake conversation • description of complaint on receipt • price estimation beforehand • prepared listing of upgrading services performed • Costs of upgrade • Upgrade time • Customer service – service guarantee – exchange appliance during upgrade	Survey of consumers' experiences
Satisfaction with upgrade	• Damaged appliance • Could not remedy faults • Expected upgrade not attained, more improved components to replace or install	Survey of consumers' experiences

3.2.1.1 Availability and price of improved components

RESEARCH METHOD

The data can be collected via a telephone survey of retailers who offer improved parts. Another way to obtain relevant data is via a questionnaire on consumer experiences of upgradability. Questions concern the price, and the delivery period if improved components have to be ordered. A comparison can be made between the availability of improved components suitable for only one product and interchangeable and standardised components.

Evaluation of the availability of spare components:

(- -) Not available
(-) Long waiting time and high purchase price
(#) Poor availability
(+) Good availability
(++) Good availability and standardised

3.2.2 Disassembly[16]

KEY QUESTIONS

1. Is it possible to reach the defective component in order to replace it?
2. How much time do consumers need, on average, to disassemble the appliance in order to reach the defective component?
3. What tools do consumers need for disassembly? Are standard or special tools needed?
4. Is disassembly difficult for consumers?
5. Is it safe to disassemble the appliance?

RESEARCH METHOD

The data can be collected through an inventory and a laboratory disassembly simulation test, with an expert panel of up to three people. Another way to collect data is a consumer panel test using at least 20 people.

ASSESSMENT: Disassembly

The assessment with a disassembly simulation test is based on overall disassembly time, which automatically covers complexity of construction and difficulty of disassembly. Besides overall disassembly time, it is necessary to record the number and types of connections, required tools, and the difficulty of disassembly.

The assessment of disassembly consists of the following criteria:

- total disassembly time
- type of connections
- number of connection types
- number of connections of one type
- number of necessary tools
- special or non-universal tools
- safety of disassembly.

EVALUATION: Disassembly

(- -) Disassembly not possible, either because it is not possible to open the appliance, or because it would destroy the appliance

(-) Problems with disassembly; disassembly is difficult (obstructed, or requires high precision, or much force); long disassembly time (for coffee-makers more than 15 minutes); special tools needed

(#) Possible problems with disassembly, if problems in chassis and plastic parts, or if there is a glued connection

(+) No problems for disassembly; disassembly time is reasonably good; arrangement of chassis and plastic parts cause no problem; the connections are screw or click type

(++) Disassembly with few actions, short disassembly time (for coffee-makers less than four minutes); 'sandwich' construction (for disassembly, the components are removed in one uniform direction).

3.2.3 Installation of improved components, re-assembly

KEY QUESTIONS

1. Can consumers install the improved component and re-assemble the appliance without difficulties?
2. Is there at least one vacant connections for the improved component?
3. Are disassembly and re-assembly non-destructive?
4. Is re-assembly the reverse process of disassembly?

RESEARCH METHOD

The data can be collected via inventory and disassembly simulation test in a laboratory, with an expert panel (at least three). Another way to collect data is a consumer panel test (at least 20).

ASSESSMENT: Re-assembly

The assessment of re-assembly is dominated by the overall installation and re-assembly time (as with disassembly). A second criterion is the reversibility of re-assembly.

The assessment of re-assembly is on the following criteria:

- overall installation and re-assembly time

- is re-assembly the reverse process of disassembly?

- is disassembly a reversible process, and are the same tools needed for re-assembly as for disassembly (is soldering of connections needed)?

- is the sequence of re-assembly the reverse of disassembly (possibility of parts left over)?

- can replacement of the improved component be performed in only one way?

Evaluation of re-assembly:

(- -) Disassembly is destructive, or re-assembly did not succeed

(-) Improved component is installed with special tools

(#) Reasonable re-assembly, actions the same as with disassembly

(+) Easy re-assembly, improved component replaceable in only one way

(++) Re-assembly is the reverse of disassembly, short re-assembly time

3.2.4 Tracing and mending faults

KEY QUESTIONS

1. Can consumers trace and mend faults in a short time without difficulty?
2. Do manufacturers give support to consumers on what to do and where to go?

RESEARCH METHOD

The data can be collected via inventory and fault simulation test in a laboratory, with an expert panel (at least three people). Another way to collect data is a consumer panel test (at least 20 people), or a consumer experience survey (at least 1,000) to get data on the most frequent faults, and tracing and mending times.

[16] As in the disassembly guidelines in the Repairability module.

3.3 DIY upgrading: weighting the criteria of upgradability

The proposed weighting factors are:

Assessment criterion	Weighting factor %
Information to consumers	20
Availability of improved components	20
Disassembly	40
Installation and re-assembly	20

3.4 Upgrading services

3.4.1 Requesting support

KEY QUESTIONS

1. Can consumers make a balanced decision about which upgrading service to select?
2. Do manufacturers give information and guidelines to consumers about what to do and where to go?

RESEARCH METHOD

The information is collected via an inventory of the manual. Consumer organisations can advise consumers which upgrading service to select by assessing them in a mystery shopping experiment.

3.4.2 Service

KEY QUESTIONS

1. What experiences do consumers have of the different types of upgrading services?
2. Does the upgrading service give a receipt beforehand containing diagnosis, maximum price and date of delivery?
3. What are the costs of the upgrade?
4. What is the upgrade time?
5. What is the quality of customer service given by the upgrade service?

RESEARCH METHOD

Data collected about consumers' experiences of upgrading services are collected via a consumer survey. Alternatively, upgrading services may be assessed by testing how well they upgrade defective appliances. Mystery shoppers take an appliance with a previously well-defined functional gap to an upgrading service. Acquiring appliances with the same functional gap and the same age will be difficult. If possible new appliances can be used.

ASSESSMENT: Upgrading services

The assessment of the upgrading service is on the diagnosis previously made by the upgrading service, the quality of the upgrading service, and the customer service:

- determination of consumer demand for improvement
- does the upgrading service ask relevant questions about requirements, complaints?
- does the upgrading service give a receipt to the consumer?
- does the receipt include the complaint and the upgrading strategy (listing of upgrading services) for the appliance?
- does the receipt include a price estimate for the upgrading, and date of delivery?
- is the upgrade strategy given by the upgrading service technician correct?
- quality of upgrading service
- service
- costs of upgrade
- upgrade time
- customer service
- replacement appliance during upgrading?
- does the upgrading service give an upgrading guarantee?

3.4.3 Satisfaction with upgrade

KEY QUESTIONS

1. What is the overall satisfaction with the upgrading service?
2. Has the upgrade succeeded or not?

RESEARCH METHOD

Data on satisfaction with upgrading is collected along with answers to questions in the consumer experience survey.

Green test programme for colour TVs

This environmental sub-programme is an addendum to the research programme Colour Television receivers – IT-test programme, edition: 1998, VI.0.

This sub-programme consists of three parts.

Part 1: Non-brand-specific information on repairability and recyclability of colour television receivers

This part consists of the following three general non-brand specific aspects of repairability of colour television receivers:

1. Vulnerability of colour television receivers, and consumer experiences of repairing broken televisions
2. Quality of repair services
3. Waste collection, recycling facilities and legislation.

1 Vulnerability of colour television receivers

Picture tube problems are the most common faults in colour television receivers.[1]

A Consumentenbond study found that 61% of consumers (n = 1,400) had problems when their colour television receiver was, on average, seven years old. Eighty per cent of owners repaired their broken television, 90% of them choosing to have it mended by a repair service. The most frequent symptoms were bad picture quality and colour deviations (29%), and no picture at all (19%).[2]

The research options for investigating the most common symptoms and problems, the most vulnerable parts, and the age of faulty televisions are given in Appendix A.

2 Quality of repair services

2.1 Consumer questionnaire
2.2 Mystery shopping exercise

2.2 Mystery shopping

The quality of repair services can be investigated in a mystery shopping exercise. Well-briefed mystery shoppers take an appliance with a typical defect to repair services. Acquiring appliances with the same defect and the same age will be difficult, so it is better to use new appliances that have been deliberately given a well-defined defect. For colour television receivers, a defect in the power supply is a good choice.

An example of a mystery shopping experiment for colour television receivers was carried out in 1992 by Consumentenbond[3]. The defects introduced were: a defective resistor in the power supply, a defective fuse and a defective back-up battery. Another example of a mystery shopping experiment, with VCRs, was performed in 1997 by the Verbruikersunie.[4] They introduced a simple defect to the power supply (defective resistor) in order to use the same appliance again for more repair services. In Appendix B, a protocol for the mystery shopping study is given.

The following aspects have to taken into account in a mystery shopping exercise:

2.2.1 presentation, registration and service in repair shop
2.2.2 receipt
2.2.3 estimate of repair costs
2.2.4 threshold value for maximum repair costs and assurance that consumer will be informed if threshold is crossed

[1] Green guidance, page 35
[2] Consumentengids February 1997, page 46-48. Consumer reports, May 1998, page 17
[3] Consumentengids July 1994
[4] Test-Aankoop Magazine nr. 404 November 1997 getting things fixed II, report T-2276, Carol S. Sherwin, March 2 1998

2.2.5 itemised bill
2.2.6 functioning of colour television receiver after repair
2.2.7 quality of repair
2.2.7 price
2.2.9 warranty
2.2.10 period of repair
2.2.11 replacement appliance offered

The assessment of the repair service is based on (1) the diagnosis made by the repair service, (2) the quality of the repair service, and (3) the customer service.

3 Waste collection, recycling facilities and legislation

Information about local facilities for recycling and waste collection and national legislation can be obtained by a survey of manufacturers. This information may be important in the weighting of the different categories of assessment criteria. An example of a questionnaire developed in an international test programme by International Testing on the recyclability and repairability of small domestic appliances such as shavers, toasters, irons, vacuum cleaners, deep fat fryers and microwave ovens is given in Appendix C More information about recycling facilities, waste collection and legislation on recycling large domestic appliances is given in ‘Sustainable Consumption’ in the Introduction & background section of *Green testing.*

Part 2: Repairability

Assessment of the repairability of colour television receivers within comparative testing falls into two main categories:

1. Diagnosis of defect
2. Warranty coverage
3. Selection of repair service
4. Indication of costs of research on repairability.

DIY repair of televisions is not taken into account due to the fact that 90% of consumers use a repair service. However, information on troubleshooting and how to fix simple defects is very useful and a prerequisite for a good manual – and, for the 10% of DIY repairers, more detailed information is essential.

1 Diagnosis of defect

1.1 Product inventory: information to the consumer Information in the users' manual, and information available to consumers:

- 1.1.1 troubleshooting list, naming the most vulnerable components
- 1.1.2 expected useful life span of vulnerable components
- 1.1.3 repair / disassembly procedures for replacing vulnerable components
- 1.1.4 illustrations of repair / disassembly
- 1.1.5 required tools
- 1.1.6 service addresses.

1.2 After-sales support

The quality of information available to the consumer via helplines is tested through a telephone survey. Questions must represent a typical symptom of a broken appliance. In this case, use of one of the most common symptoms – ie no picture at all – is not recommended. Alternatively, a problem can be chosen with the programming or with Teletext, where the consumer can be helped to solve the problem.

An example of the way the service level of helplines can be evaluated has been drawn up, for computers, by the Consumers' Union.[5] No ready-to-use guidelines are available for colour television receivers.

However, important aspects to check are:

- do manufacturers help customers with general questions?
- do manufacturers help locate a local, authorised repair shop (where you'll invariably have to go for service under warranty or to obtain genuine replacement parts), or provide technical assistance to troubleshoot problems?

For colour television receivers, the following criteria are relevant for the assessment of after-sales support:

1.2.1 menu of choices, number of levels between the caller and the technical support representative, waiting times

1.2.2 quality of customer service (courteous and knowledgeable)
1.2.3 toll-free / freefone
1.2.4 representative asks for zip-code / postcode, name, address and phone number (on warranty card), model number
1.2.5 procedure to verify the warranty (ease of convincing manufacturers that the appliance was bought less than a year ago, sales receipt not available because it was a gift)
1.2.6 length of time on the phone
1.2.7 number of calls
1.2.8 quality of advice.

If available, after-sales service available on Internet can also be taken into account.

The quality of help-lines is evaluated on a 5-point scale for the aspects: accessibility by telephone, service treatment, and quality of advice.

2 Warranty coverage

- Product inventory: inventory of the manual
- Check on the guarantee conditions
- Telephone survey of manufacturers
- Survey of consumer experiences

A (critical) analysis of the possible benefits of an extended warranty is carried out at the same time as the survey of consumer experiences.

Evaluation of warranty coverage is based on the ratio of the expected economic life span and the guarantee period given. In general, the policy of consumer organisations towards warranties is based on a balanced ratio between warranty period and expected economic life span.

3 Indication of costs of research on repairability

Estimation of the costs for research on repairability is based on a study involving 20-30 products or repair services.

Type of research	Duration	PO time	Costs(1)
	weeks	hours	Euros
After-sales service	1	16	500-1000
Mystery shopping exercise	2-6	120	10,000-20,000
Product inventory	1	2-8	< 500

(1) out-of-pocket costs excluding PO costs and sample costs

Part 3: Recyclability

The assessment of the recyclability of colour television receivers consists of three main categories:

1. Information to the consumer on recyclability
2. Environmentally harmful substances
3. Disassembly
4. Indication of costs of research on recyclability

We propose the following priority-setting for assessment categories:

	Weighting percentage %
Information to consumers	20
Environmentally harmful substances	20
Disassembly process	20
Material recyclability	40

1 Information to consumers on recyclability

Assessment of the information on recycling available to consumers in the users' manual, and elsewhere, consists of the following:

1.1 information about how and where consumers can dispose of the appliance
1.2 manufacturer's claimed strategies for recycling: collection of colour television receiver after use
1.3 recycling guarantee: mention of whether a recycling guarantee is given when a new system is bought
1.4 information about avoiding heavy metals like cadmium, as well as other harmful materials like PVC and halogenated flame retardants
1.5 information about location of components containing environmentally harmful substances

Additionally, there should be full information about the different electrical and electronic components and materials used in the appliance, especially for automated disassembly in a recycling plant (eg a microchip containing this information in the appliance).

The criteria mentioned above should be rated on a five-point scale.

2 Environmentally harmful substances

The assessment of environmentally harmful substances in colour television receivers consists of:

2.1 a product inventory to check for the presence of rechargeable batteries
2.2 identification of halogens in plastic components
2.3 identification of flame retardants in the back and front casing and the main printed circuit board
2.4 identification of heavy metals in the tube, electronic components and plastics.

2.1 Product inventory

2.1.1 Presence of rechargeable batteries
2.1.2 Information about disposal of rechargeable batteries.

2.2 Presence of halogens

The copper wire test (Belstein experiment) is used to see whether chlorine and / or bromine is / are present in:

2.2.1 back casing
2.2.2 cabinet or front casing
2.2.3 frame and / or speaker casing
2.2.4 main printed circuit board.

2.3 Halogenated flame retardants in back casing and main printed circuit board

Only if the ‘Belstein’ results in 2.2 prove positive:

2.3.1 determination of weight percentages of antimony (Sb), bromine (Br) in back casing and main printed circuit board, by instrumental neutron activation analysis (INAA) or ICP-MS, and, if positive on bromine, then:
2.3.2 identification of specific brominated flame retardants in the back casing and main printed circuit board by pyrolysis mass-spectrometry or GC / MS.

2.4 Heavy metals

2.4.1 Determination of weight percentages of cadmium in the tube and electronic components by instrumental neutron activation analysis (INAA) or ICP-MS
2.4.2 Identification of heavy metals in (coloured plastic) parts by instrumental neutron activation analysis (INAA) or ICP-MS.

3 Disassembly

The disassembly test for colour television receivers consists of:

3.1 Disassembly into main components
3.2 Estimation of recyclability: determination of the percentage weights of different materials, and estimate of recyclability

3.1 Disassembly into main components

3.1.1 Total disassembly time
3.1.2 Disassembly time of critical components (back casing, internal wiring, deflection unit and main printed circuit board)
3.1.3 Diversity of connection types
3.1.4 Special or non-universal tools
3.1.5 Safety of disassembly.

The critical components are defined as the components for which the disassembly times vary the most. In the pilot study on colour TVs by Consumentenbond, the critical components were: back casing, deflection unit, internal wiring and main printed circuit board.

The rating on a five-point scale is based on variations within the tested televisions. Appendix B of the Recyclability module of *Green testing* gives an example of the rating based on CB’s pilot test.

In Appendices D to F, more information is given on the requirements and procedures of the disassembly test: the disassembly form, a list of abbreviations, and a protocol with requirements and procedures for the colour television disassembly test.

3.2 Estimation of Recyclability

3.2.1 Percentage weights of main components:

- 3.2.1.1 Percentage weights of components with valuable materials
- 3.2.1.2 Percentage weights of components categorised as waste
- 3.2.1.3 Percentage weights of components with environmentally harmful substances
- 3.2.1.4 Material labelling percentage: % of plastic parts > 25g labelled
- 3.2.1.5 Accuracy of labels according to ISO 11469.

The rating of percentage weights of components with valuable materials, waste, and environmentally harmful substances is based on an expert judgement and depends on

the type of appliance. An example for colour television receivers is given in Appendix B of the Recyclability module. The rating on a five-point scale is based on the differences found within the tested TVs.
Identification of plastics should be done visually with characterisation (DIN 54840, DIN 7728 part 1) in combination with a copper wire test.

3.2.2 Recyclability of materials:

- 3.2.2.1 Suitability for high-grade recycling (of large plastic components > 25g, tube, printed circuit boards)
- 3.2.2.2 Presence of incompatible plastics in back and front casing
- 3.2.2.3 Separation of incompatible plastics in back and front casing
- 3.2.2.4 Separation of non-glass parts from the tube
- 3.2.2.5 Amount of supporting non-metals on printed circuit boards

Estimate the potential material reprocessing percentage.

The rating on a five-point scale is based on the differences found within the appliances tested. An example for televisions, based on the CB pilot study on four brands, is given in Appendix B of the Recyclability module.

4 Indication of costs of research on recyclability

Type of research	**Duration weeks**	**PO time (1) hours**	**Costs Euros**	**Costs per analysis**
Copper wire test				
Determination of plastics	1-2	2-4	40-100 (2)	10-25
INAA	4	4	320 (2)	80
Disassembly test	4	24		5.000-10.000 (3)
Product inventory	1	4-8		<500 (3)

(1) based on a total number of 10-20 models in the test
(2) estimated 4 samples per model; excluding sample costs
(3) total costs with one sample of each model in the test

Appendix A.

Information on the vulnerability of colour television receivers

Information on the vulnerability of colour television receivers can be obtained from the most frequent symptoms and complaints, the most vulnerable parts, and the age of broken televisions. In the research below, options are given for testing the vulnerability of appliances.

Most frequent symptoms and complaints, most vulnerable parts

Depending on the information available, the following options are available to get information about the vulnerability of televisions:

1. questionnaire to manufacturers
2. questionnaire to consumers for qualitative indication (n @ 100)
3. expert opinion (testing laboratories, repair services)
4. literature study
5. questionnaire to consumers (n > 1,000)

The first four options give qualitative information. The last option results in quantitative information based on consumer experiences. An example of a questionnaire to consumers is available (in Dutch) from Consumentenbond.

Age of broken televisions

Information on the age of broken televisions and consumer experiences can be obtained by a questionnaire to consumers (n > 1,000). In the survey, attention can be paid to the repair decision consumers make when they have to deal with a broken colour television.

The costs of a consumer survey depend on the number of questionnaires. Handling costs vary from 2,500-5,000 Euros for a test with 1,000 to 2,000 questionnaires.

Appendix B.

Requirements and procedures for mystery shopping

Requirements

- Set of colour televisions (market leading brands)
- Experienced technician or repairer
- Experienced mystery shoppers
- Form to record results
- Instructions for mystery shopping exercise.

Procedure

1. Introduce a defective resistor into the power supply and encode discreetly the components that may be exchanged by the repair service to fix the defect

2. Draw up a protocol for the mystery shopping experiment where all aspects mentioned in 2.2 are taken into account:
   - clear instructions to mystery shoppers about the questions that have to be asked of the repair service, and how to respond
   - form to record results

3. Evaluate the mystery shopping procedure in a pilot test before the real investigation starts

4. Mystery shopping visit to repair shops

5. Check the repair afterwards:
   - Compare the repair with the expert judgement of an experienced repair man
   - Compare the repair costs with the expert judgement of an experienced repairer

6. Evaluate aspects such as price, quality of repair, quality of service, etc

Appendix C.

Questionnaire on recycling and waste collection of white and brown goods

'Collection infrastructure: systems for waste collection, disassembly and recycling facilities, disposal regulations and agreements between government and manufacturers'

Name of organisation:
Name of respondent:
Address:

Introduction

We would like to receive information about the disposal regulations, collection infrastructure of disposed household appliances, facilities for disassembly and recycling in your country, and available LCAs (for the evaluation).

Most of the following questions are about the general situation concerning white and brown goods in your country. Some specific questions refer to small household appliances. We have focused on shavers, toasters, vacuum cleaners, irons, microwaves and deep fat fryers. Please type your answers in the section below each question, and send the completed questionnaire by e-mail back to jpoolman@consumentenbond.nl before 15 June 1999.

1 Facilities for recycling and waste collection, infrastructure

1.1 Practice of disposal of white and brown goods

1 How can consumers dispose of their old white and brown goods in your country? Are they being collected by the municipal waste collection service, or are there special collection points where consumers can take their old appliances for further treatment? Please describe the situation in your country.

2 Can consumers offer their old white and brown goods to the manufacturer / retailer, and do consumers have to pay for it?

3 Can you mention anything specifically about the disposal facilities of the following product groups: shavers, toasters, irons, vacuum cleaners, deep fat fryers, microwaves?

4 Do you have information about pilot projects on collecting and reprocessing white and brown goods in your country? Please describe the situation in your country.

1.2 Policy on disposal of white and brown goods

5 Does your organisation have a consistent policy, or give consistent advice to consumers on the subject of disposal of old white and brown goods in the most environmentally friendly way?

6 Does your organisation have a point of view on the development of a future collection infrastructure of white and brown goods? (Future collection infrastructure could be developed by specialised industries, which collect and reprocess, the producer collects and reprocesses, expansion of the municipal waste collection service).

1.3 Waste generated by white and brown goods

7 Do you have any statistics or information about the amount of waste from white and brown goods in your country? Please specify.

8 Do you have information about the amount of white and brown goods taken back by municipal collection points, retail trade, or possibly specialised recovery businesses? Please specify

9 Do you have information on the percentage (of waste) of shavers, toasters, irons, vacuum cleaners, deep fat fryers and microwave ovens taken back? Please specify.

2 Treatment of old appliances: state of the art

2.1 Processing of white and brown goods waste in practice

10 What happens to old white and brown goods discarded by consumers in your country? Please describe the situation in your country.

11 Do you have information about the destination of disposed shavers, toasters, irons, vacuum cleaners, deep fat fryers and microwave ovens (percentage of products re-used, re-manufactured, refurbished, recycled, disposed of)? Please specify.

12 Can you mention anything about the treatment of discarded shavers, toasters, irons, vacuum cleaners, deep fat fryers and microwave ovens?

2.2 Repair and re-use of products

13 Does your country have second-hand retailers where consumers can buy re-manufactured / refurbished white and brown goods?

14 Do you have any information on consumer purchasing habits of second-hand appliances (shavers, toasters, irons, vacuum cleaners, deep fat fryers and microwave ovens) in your country? In particular, for each product group, the numbers of second-hand and new appliances bought.

15 Are there specialised disassembly plants in your country where white and brown goods are disassembled and repaired? Please specify.

2.3 Recycling facilities

16 Are there specialised recycling plants in your country where appliances are collected and disassembled in order to recycle the materials? Do you have any information about the materials recycled?

3 National and European regulations

3.1 Disposal of white and brown goods

17 Does your country have regulations concerning collection and disposal of white and brown goods? Please type an ‘x’ in the space before the line that is applicable to the situation in your country, and go to the next question mentioned.

Yes, regulations are in force *Go to 18*
No, but regulations are in draft or in development *Go to 19*
No, none foreseen in the future *Go to 20*

18 Please give a short description of the disposal regulations for white and brown goods.
18a Who pays for the removal of old appliances (from consumers), and how much?

18b Are there any recycling percentages established for the different material parts of white and brown goods (eg plastics, metals)?
Go to 20

---

19 Please give a short description of the disposal regulations for white and brown goods in draft or in development.

19a What is the date when the disposal regulations in draft or in development come into effect?

19b Who will pay for the removal of old appliances (from consumers), and how much?

19c Are there any recycling percentages established for the different material parts of white and brown goods (eg glass, plastics, metals)?

3.2 Preventive regulations

---

20 Which harmful (amounts of) substances in the manufacturing stage of products (eg cadmium, mercury) are prohibited by law or by voluntary agreements? Please give a short reference.

---

4 Available LCAs

---

21 Do you have information available with regard to Life Cycle Analysis studies (LCAs) on the six product groups of interest: shavers, toasters, irons, vacuum cleaners, deep fat fryers and microwave ovens? Please can you give a short description of the available LCAs. Could you please send the available LCAs before 15 June 1999.

Appendix D.

Requirements and procedures of the disassembly test of colour television receivers

Requirements for the preparation of disassembly test

- Experienced ‘disassembler’
- Record-keeper
- Disassembly location, pneumatic tools
- Stopwatch
- Balance (max 100 kg, with a relative accuracy of +/-50 gram); small weights are measured on a balance with an accuracy of +/-1 gram
- Storage facility for samples (many trays)
- The appliance to be disassembled
- Disassembly guideline for the product group (disassembly level, and sequence of disassembly)
- Standard disassembly form.

Disassembly test procedure

1. Select the component to disassemble.

2. Set out the necessary tools.

3. Start with disassembly. At a signal from the record-keeper, the disassembler starts to disassemble the component in uninterrupted actions. The record-keeper measures the time with the stopwatch. The time stops at the moment when the disassembler has laid the component aside. Any released screws and other connectors are collected in a separate assembling tray (after the test all the screws are collected and weighed).

4. For each disassembled component, the record-keeper writes down:
   - recorded disassembly time
   - type of connections (or connectors)
   - number of connections (or connectors) needed to be loosened to be able to disassemble the component (if several connections can be loosened with one action it counts as one connection)
   - special remarks (safety during disassembly, for example spring constructions under tension)
   - weight of the component
   - composition of materials
   - labelling
   - tools required
   - name and code of the component; each component will be deposited in a separate tray.

5. Return to point 1, until the appliance is fully disassembled.

Appendix E.

Disassembly form

Brand
Type
Production year
Tube diameter cm
Sample Number

Disassembly location
Disassembler
Registrator
Date

Component	Part	Sample code	Disassembly time (sec)	Connections						Tools			Obligatory disassembled previous part (sample code)	Difficulty rating (0=low, 1=medium, 2=high)			Special remarks
				type 1 (from list)	amount 1	type 2	amount 2	type 3	amount 3	tool 1 (from list)	tool 2	tool 3		obstruction	required precision	force	
External cables	External cables																
	Connectors																
Back panel	Back panel																
Air inlet																	
Internal wiring	Wires																
	Connectors																
Print 1	On tube																
Print 2																	
Back panel																	
Deflective unit																	
Degausing ring																	
Speakers																	
Tube																	
Prints																	
Front panel																	
Screws (all)																	
TOTAL			(min)														

Possible to enter after disassembly:

Value (Euro)

Component	Part	Mass g	Main material fractions in %: Tube glass	Ferrous	Plastics	Wood	Copper(wire)	Aluminium	Circuit board	Others	LABELS (yes/no)	Contents	>0/ton Category Value	0 - -100/ton Waste	<-200/t Harmful Hazardous	Optional Flame retardants: Cl%	Br%	Sb%
External cables	External cables Connectors																	
Back panel	Back panel																	
Internal wiring	Wires Connectors																	
Print 1																		
Print 2																		
Back panel																		
Deflective unit																		
Degausing ring																		
Speakers																		
Tube																		
Prints																		
Front panel																		
Screws (all)																		
TOTAL																		

Appendix F.

List of abbreviations to use when completing Disassembly form

Connections with their letter codes

CG Card guide
BP Breaking points
SC Screw
CP Clamp
CL Click
EC Electrical connector
TA Tape
MC Material cut
BF Bayonet fitting
ST Staple
GL Glue
SO Solder
WE Weld

Tools with their letter codes

Unscrewing

TS Torx screwdriver
FS Flat-head screwdriver
CS Cross-head screwdriver
OS Other screwdriver
FW Fixed-end wrench
AW Adjustable wrench
SR Socket with ratchet
AK Allen key
PW Power wrench

Cutting and breaking

KN Knife
WC Wire cutter
PT Pair of tongs
SH Handheld shears
DR Drill
PG Handheld power grinder
GW Grinding wheel
HS Hacksaw
JS Jigsaw
BS Power band saw
HM Hammer
AL Awl

Gripping and prying

VS Vice
Pl Pliers
CH Chisel
CB Crowbar

Other

BR Brush
RG Rag
ST Special tool
MA Manual+gloves

Consumers International
Programme for Developed Economies and Economies in Transition
24 Highbury Crescent
London N5 1RX, UK
Tel: +44 171 226 6663
Fax: +44 171 354 0607
e-mail: consint@consint.org.uk
Web site: http://www.consumersinternational.org

About Consumers International

Founded in 1960, Consumers International (a non-profit organisation registered in The Netherlands as the International Organization of Consumers Unions, registration number S1 49999) is a federation of consumer organisations dedicated to the protection and promotion of consumer interests worldwide through institution building, education, research and lobbying of international decision-making bodies. An independent, non-profit foundation, Consumers International has over 230 members in more than 100 countries.

Regional Offices
Asia and the Pacific, P.O. Box 1045, 10830 Penang, Malaysia
Tel: +60 4 229 1396 Fax: +60 4 228 6506 e-mail: ciroap@pc.jaring.my
Latin America and the Caribbean, Las Hortensias 2371, Providencia, Santiago, Chile
Tel: +56 2 335 1695 Fax: +56 2 231 0773 e-mail: consint@entelchile.net
Africa, Private Bag A6215, Avondale, Harare, Zimbabwe
Tel: +263 4 302 283 Fax: +263 4 303 092 e-mail: roaf@harare.iafrica.com